AFRL-HE-WP-TR-2002-0021

UNITED STATES AIR FORCE RESEARCH LABORATORY

Assessment of the Subsonic Noise Environment in the Nellis Range Complex

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January 1993

Interim Report for the Period June 1991 to January 1993

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TECHNICAL REVIEW AND APPROVAL

AFRL-HE-WP-TR-2002-0021

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

MARIS M. VIKMANIS
Chief, Crew System Interface Division
Air Force Research Laboratory

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	January 1993	Interim - June 1991 to January 1993

4. TITLE AND SUBTITLE Assessment of the Subsonic Noise Environment in the Nellis Range Complex	**5. FUNDING NUMBERS** PE - 62202F PR - 7757 TA - 7757C1 WU - 7757C101
6. AUTHOR(S) Kenneth D. Frampton, Michael J. Lucas, Kenneth J. Plotkin	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Wyle Research Wyle Laboratories 2001 Jefferson Davis Highway Arlington VA 22202	**8. PERFORMING ORGANIZATION REPORT NUMBER** WR93-3
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Research Laboratory, Human Effectiveness Directorate Crew System Interface Division Aural Displays and Bioacoustics Branch Air Force Materiel Command Wright-Patterson AFB OH 45433-7901	**10. SPONSORING/MONITORING AGENCY REPORT NUMBER** AFRL-HE-WP-TR-2002-0021
11. SUPPLEMENTARY NOTES	
12a. DISTRIBUTION AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.	**12b. DISTRIBUTION CODE**

13. ABSTRACT *(Maximum 200 words)*

The Nellis AFB Range covers over 13,000 square miles of southern Nevada. Numerous US Air Force aircraft operate within this range on a regular basis, participating in various forms of combat-readiness training. It is the purpose of this report to quantify the noise levels associated with subsonic operations and to evaluate the resulting environmental consequences. Nellis Range noise level predictions were accomplished using current US Air Force ROUTEMAP and NOISEMAP technology in conjunction with Nellis AFB operations information. The operations information was analyzed and reduced to reflect the operating conditions within the Nellis AFB Range. This information was then joined with ROUTEMAP and NOISEMAP computer models to calculate the noise environment. A total of four operating scenarios were analyzed for this report and then scaled for the busiest month of 1992. The noise levels for the Nellis Range Complex are presented in the form of composite contours. In the case of the three Military Training Routes (MTRs), the noise levels for various lateral distances from the MTR centerline are reported. It was found that, in all airspaces, the Day/Night Average Sound Levels were within normally acceptable land-use compatibility guidelines.

14. SUBJECT TERMS noise, noise modeling, aircraft, aircraft noise, ranges	**15. NUMBER OF PAGES** 78
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

Standard Form 298 (Rev. 2-89) (EG)
Prescribed by ANSI Std. 239.18
Designed using Perform Pro, WHS/DIOR, Oct 94

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1.0 INTRODUCTION

The Nellis AFB Range covers over 13,000 square miles of southern Nevada. Numerous U.S. Air Force aircraft operate within this range on a regular basis, participating in various forms of combat-readiness training. It is the purpose of this report to quantify the noise levels associated with subsonic operations and to evaluate the resulting environmental consequences.

Nellis Range noise level predictions were accomplished using current U.S. Air Force ROUTEMAP technology in conjunction with Nellis AFB operations information. The operations information included Red Flag Mission Debriefing System (RFMDS) tracking data, Air Combat Maneuver Instrumentation (ACMI) tracking data, Nellis AFB Range Group scheduling records, and the 57th Fighter Wing scheduling records. Each of these sources of operations information was analyzed and reduced to reflect the operating conditions within the Nellis AFB Range. This information was then joined with the ROUTEMAP and NOISEMAP computer models to calculate the noise environment.

A total of four operating scenarios were analyzed for this report. These included Red Flag 91-5 (15 August 91—25 September 91), Red Flag 92-4 (20 June 92—1 August 92) and Green Flag 92-5 (15 August 92—26 September 92) from the RFMDS tracking data, and ACMI tracking data from 1 April 92 through 31 September 92.

The range subdivisions used under the RFMDS tracking system include Caliente MOA, Coyote MOA, R-71, R-74, R-75, R-76, EC South, EC East, EC West, Pahute, Reveille MOA, R-4808 W. This area is collectively referred to as the RFMDS arena and is designated by the highlighted region in Figure 1. The coordinate center for the RFMDS tracking system is designated by a cross-hair in Figure 1.

Operations under the ACMI tracking system are restricted to the Elgin MOA with some use of the Caliente MOA. This area is referred to as the ACMI arena and is shaded in Figure 2. The coordinate center for the ACMI tracking system is shown as a cross-hair in Figure 2. The remainder of the

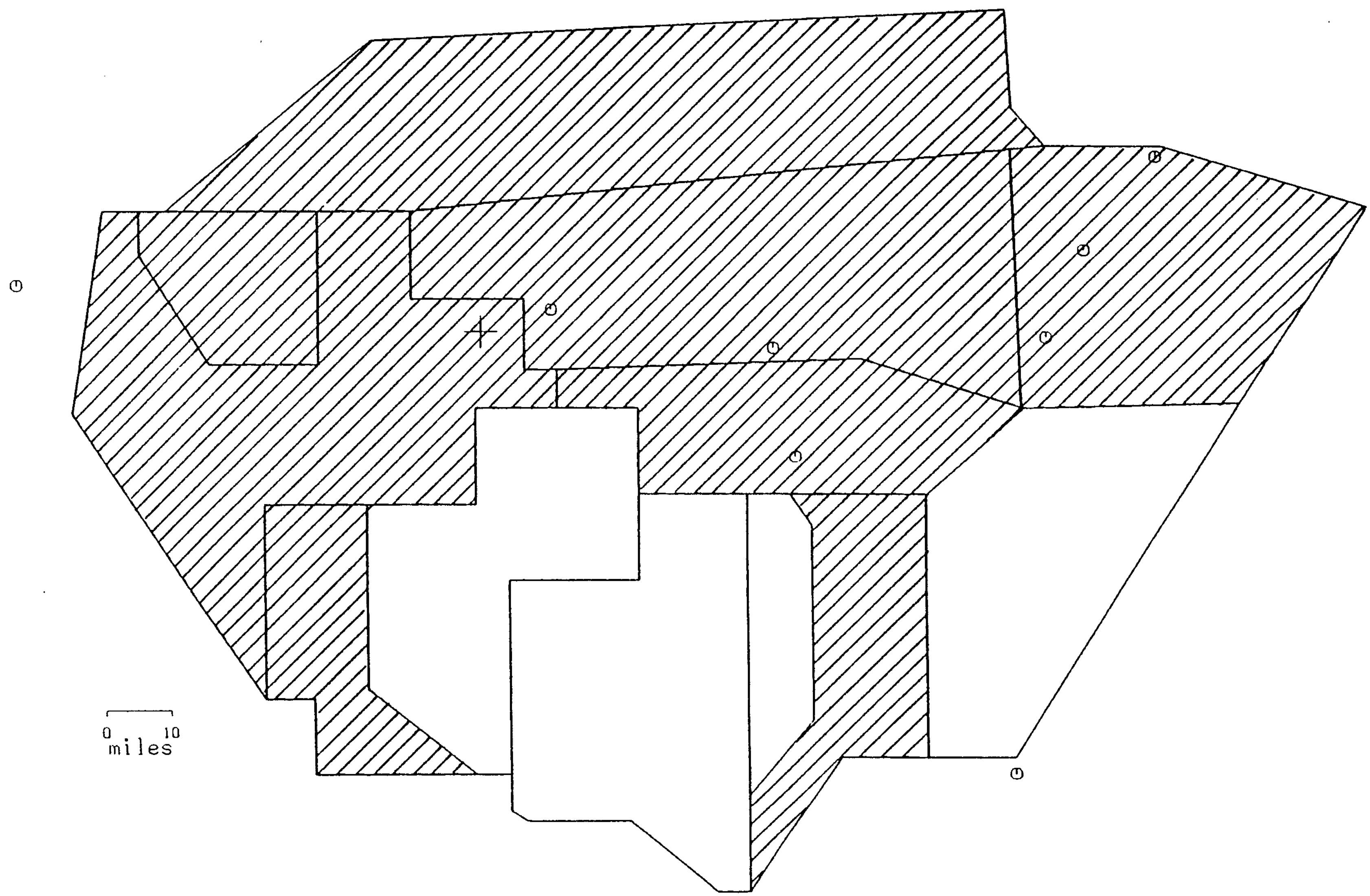


Figure 1. RFMDS Arena of the Nellis Range Complex.

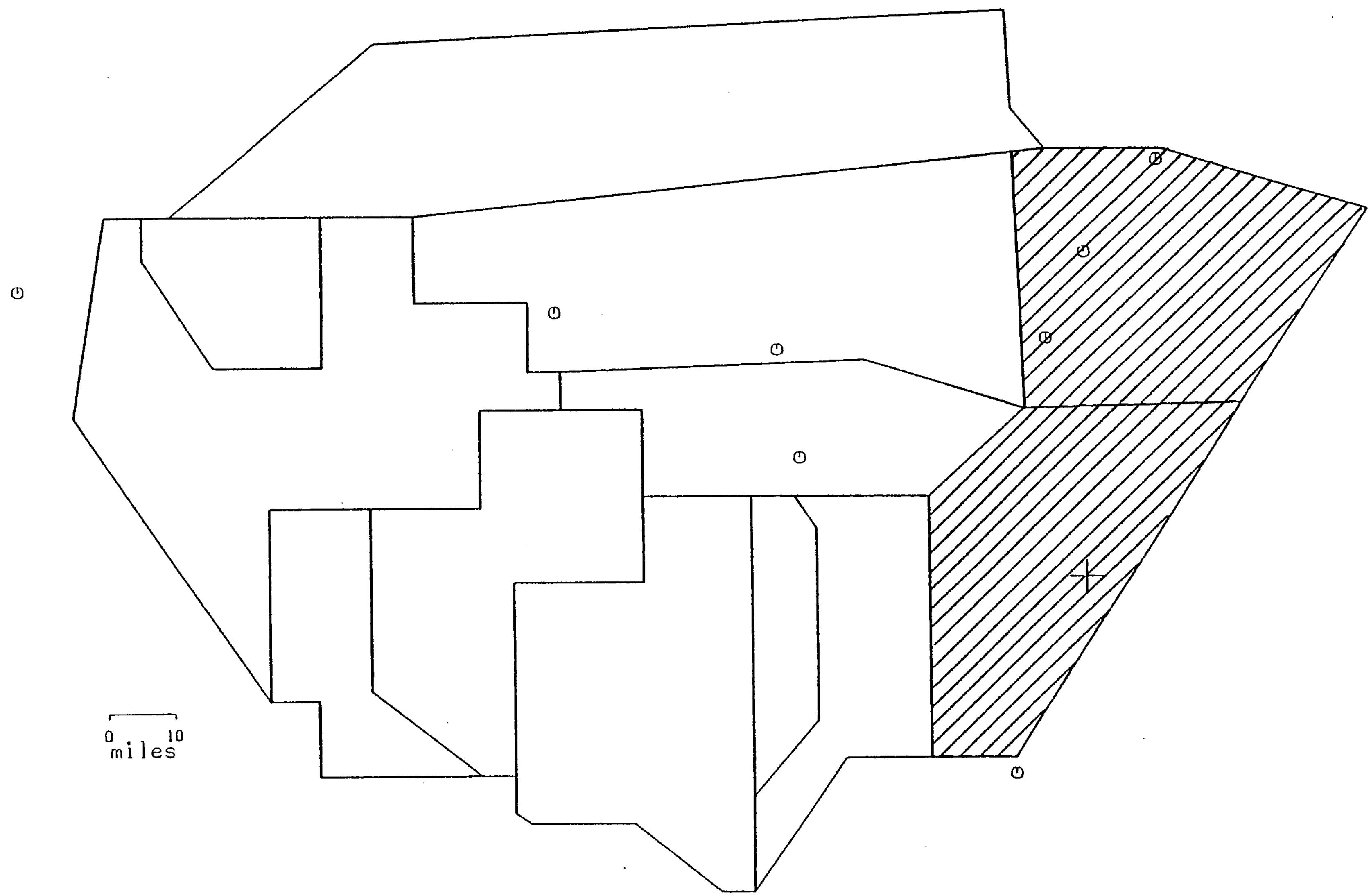


Figure 2. ACMI Arena of the Nellis Range Complex.

Nellis Range complex consists of R-61, R-62, R-63, R-64, R-65, Alamo, and R-4808 East, and is referred to as the "other" airspace in this report. These range subdivisions are shaded in Figure 3 with the exception of R-4808 East where no flight activity occurs.

Specific descriptions of each source of operations information are covered in Section 2 of this report along with discussion of the analysis performed. Procedures for calculating the noise levels within the range are also covered in Section 2. A summary of the noise levels within the range and the environmental impacts of these levels are covered in Section 3.

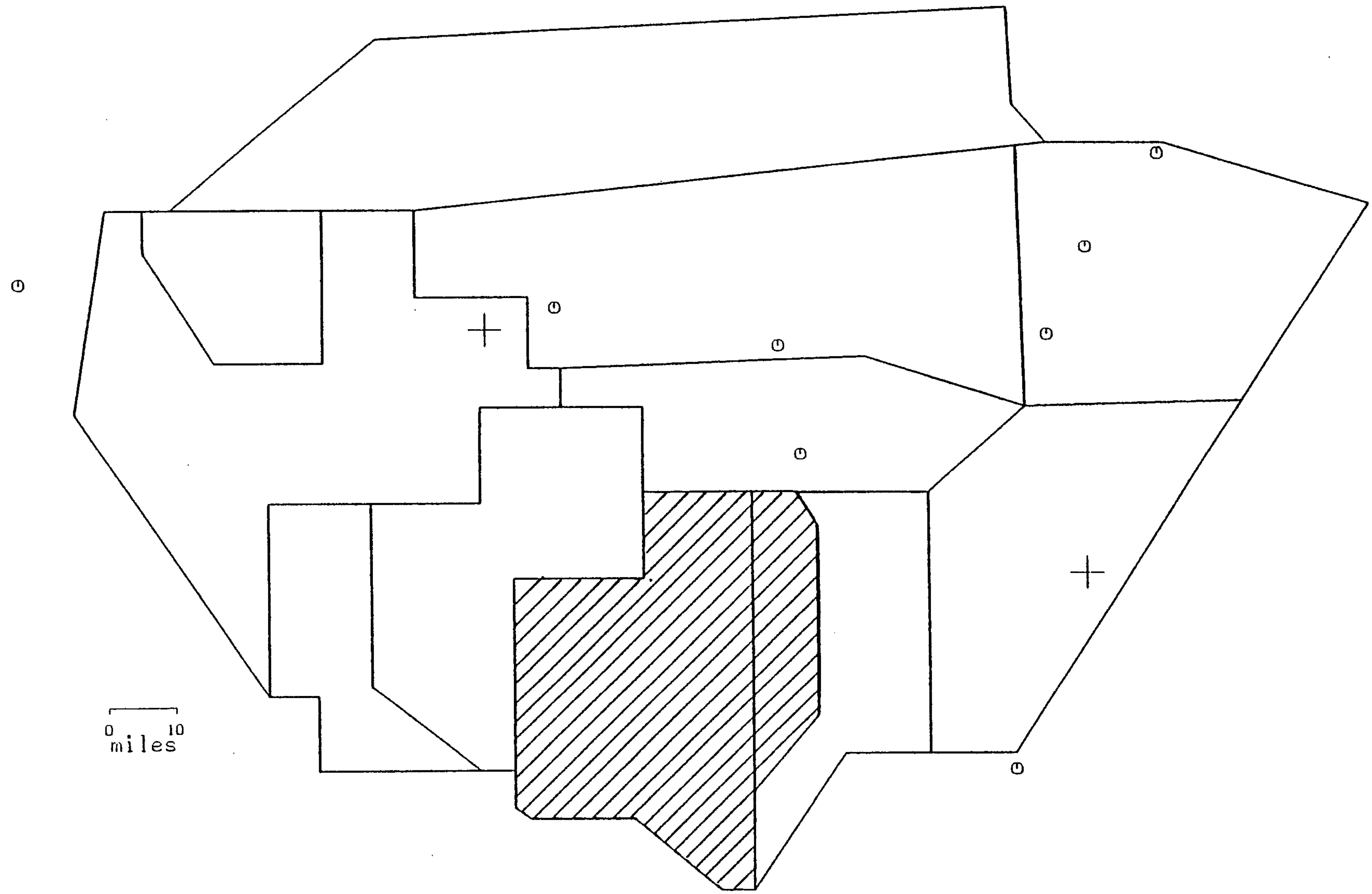


Figure 3. "Other" Arena of the Nellis Range Complex.

2.0 ANALYSIS

This section describes the analysis performed and calculations made to estimate the noise levels within the Nellis AFB Range. Analysis consisted of applying computer programs to the RFMDS and ACMI tracking data to obtain the spatial and altitude distributions of aircraft operations. These distributions served as statistical operations models and were applied to the total operations as reported in the Nellis AFB Range Group and 57th Fighter Wing schedules. This data was used in conjunction with the U.S. Air Force ROUTEMAP/NOISEMAP technology to estimate noise levels.

2.1 RFMDS and ACMI Tracking Data

RFMDS and ACMI are two very similar systems which telemeter real-time flight data from specifically equipped aircraft to a base receiver. The flight data, including coordinates, velocity, angular rates, air speed, etc., are stored on magnetic tape so that pilots may review and analyze each training mission. These two tracking systems provide precise operations information which allowed typical mission profiles to be modeled. The RFMDS and ACMI tracking systems cover different sections of the Nellis Range as shown in Figures 1 and 2, respectively.

Several different types of aircraft were contained in the various data bases. The ACMI tracking data contained operations information on F-16s, F-15s, F-18s, and A-10s. Each of the three RFMDS missions contained tracking data on the F-16, F-15, F-4, F-4E, and B-52 aircraft. In addition, Red Flag 91-5 had information on the F-111 and C-130, while Red Flag 92-4 also had F-111 records. Green Flag 92-5 had, in addition, C-130 and EA-6B flight data.

The most important information obtained from RFMDS and ACMI tracking data for the purposes of noise analysis were the altitudes of operation, the spatial distribution of operations, and the time spent on the range. The combination this data served as statistical models for the operations within the Nellis Range Complex. The aircraft speed distributions were also important for determining typical flight parameters for modeling.

2.1.1 Spatial Distribution of Operations

The first step in analyzing the RFMDS and ACMI tracking data was to determine which portions of the Nellis AFB Range were being utilized by the aircraft. To accomplish this, a computer program was written which read the data for each sortie. Then, for each record (records were separated by about 5 seconds), the x and y coordinates of the aircraft relative to the appropriate tracking system coordinate center were determined.

A grid consisting of 5-mile by 5-mile blocks was constructed which spanned the entire range complex. Consecutive sortie records were placed in the appropriate grid block and the time between them was added to the cumulative block time total. As the mission data for each sortie was processed, the total time each aircraft spent in each 25-square-mile block was accumulated. The totals were then normalized relative to the block with the greatest time.

Figure 4 shows the results of these calculations for all F-16 sorties from the RFMDS operations during the Red Flag 92-4 time period. These operations cover a majority of the Nellis AFB Range complex. The area with the greatest operations time is R-74 which is near the RFMDS coordinate center.

Figure 5 shows the normalized time for all F-16 sorties from the ACMI missions. Operations under the ACMI system were concentrated in the southern part of the Elgin MOA.

Similar contours were created for each aircraft under the Red Flag 92-4 and ACMI missions. All other aircraft had similar range utilization time contours with some small variations. The normalized time contours for all other aircraft may be found in Appendix A.

2.1.2 Distributions of Speed and Altitude

Joint distributions of speed and altitude were developed from the RFMDS and ACMI tracking data. This was accomplished by stepping through each record for each sortie. The time between consecutive records was added to the appropriate bin of an altitude/speed grid. Bins were defined for every 10 knots of

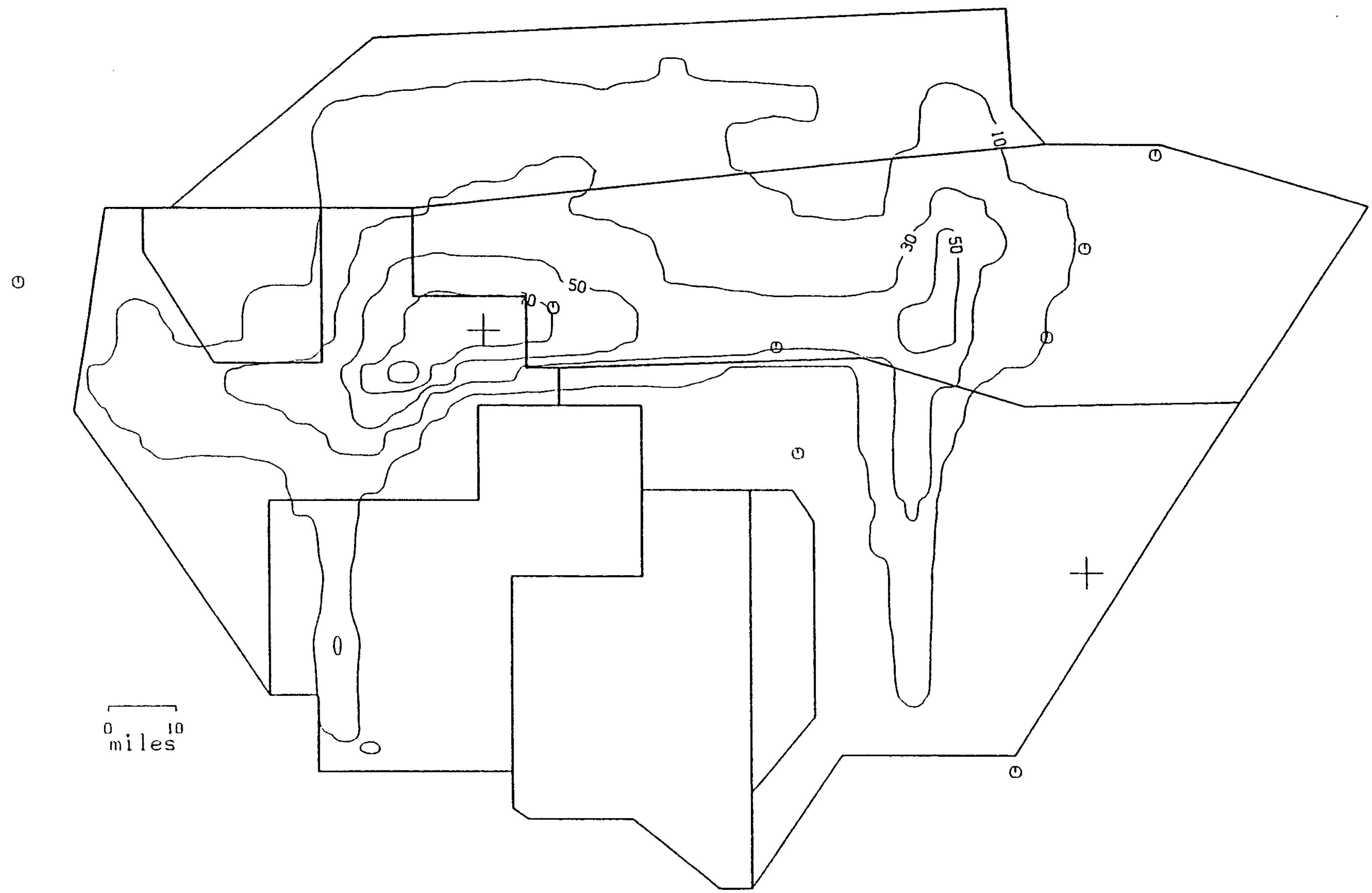


Figure 4. RFMDS F-16 Normalized Time on Range.

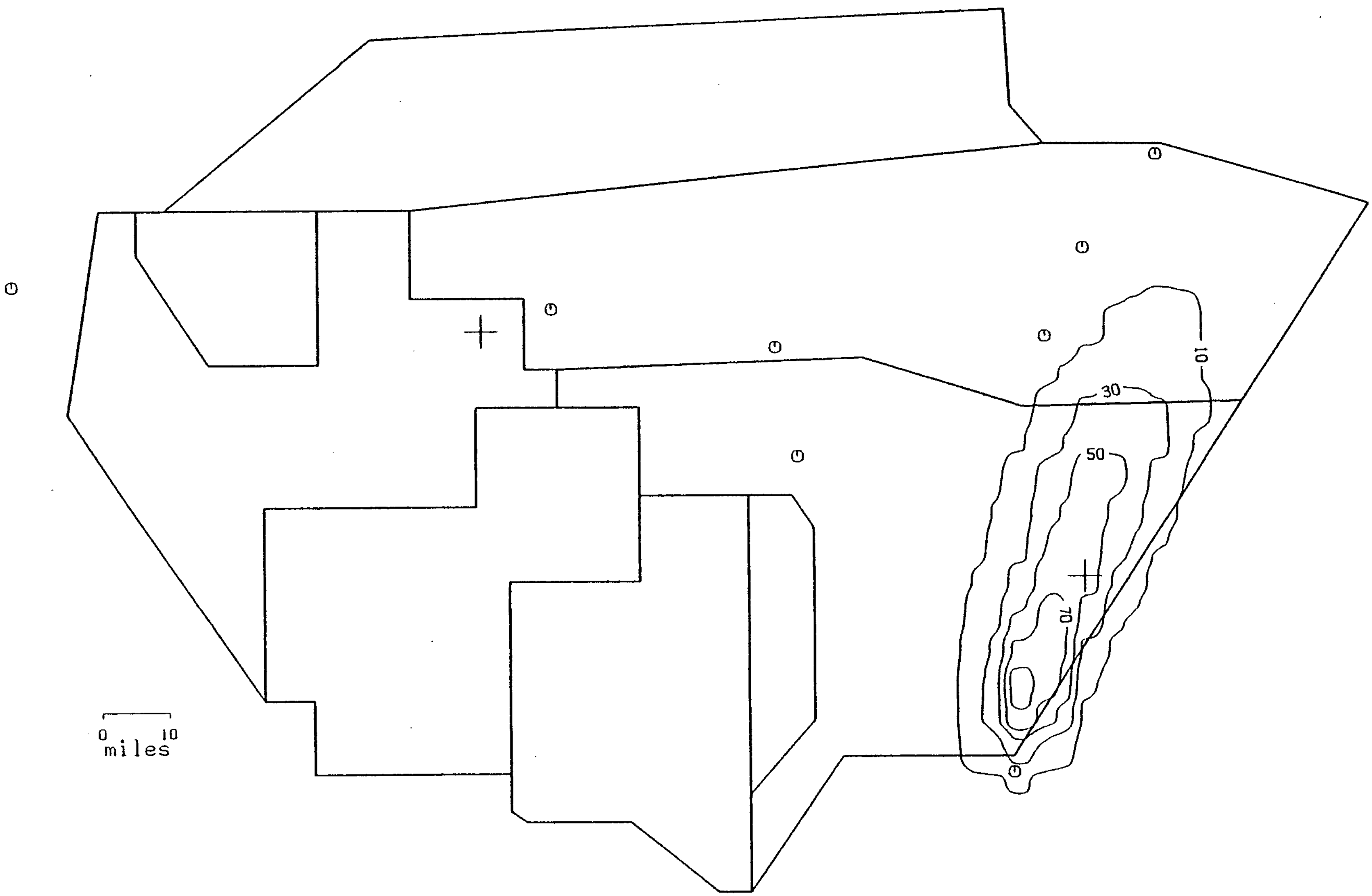


Figure 5. ACMI F-16 Normalized Time on Range.

air speed and for every 500 feet of altitude. The data for each sortie in each mission were used to produce distributions for each aircraft. The distributions were then normalized relative to the total sortie time.

The altitude reported in the RFMDS or ACMI record was relative to Mean Sea Level (MSL). Calculation of noise levels on the ground requires that the altitude Above Ground Level (AGL) be obtained. This was accomplished by referencing the latitude and longitude coordinates of the aircraft to ground elevation data from USGS digital elevation model (DEM) data. The DEM data provided the altitude of the ground under the aircraft in feet MSL. The MSL surface altitude was subtracted from the MSL aircraft altitude reported in the RFMDS or ACMI data file to obtain the AGL altitude of the aircraft.

Distributions were created for all aircraft in the Red Flag 92-4 and ACMI missions. Figure 6 shows the altitude/speed distribution for F-16 aircraft relative to AGL from the RFMDS operations. Figure 7 shows the distributions for F-16 sorties from the ACMI operations relative to AGL.

The altitude/speed distributions for all other aircraft may be found in Appendix A. There are significant differences in flight envelopes from one aircraft to another. These differences are apparently due to variations in aircraft performance and mission profiles.

The aspect of the altitude/speed distributions that is most important to noise calculations is the altitude distribution of operations. While the speed distributions were important for modeling aircraft operations parameters, they were not explicitly used in the analysis.

Altitude distributions were constructed from the joint altitude/speed distributions by summing the time spent at all speeds for each altitude. Figure 8 shows a histogram of the AGL altitude distribution for the Red Flag 92-4 RFMDS F-16 operations. Similarly, Figure 9 shows the altitude distribution for F-16 sorties from ACMI operations.

Note that the RFMDS operations occurred at a much lower altitude than the ACMI operations. This reflects the difference in mission scenarios. ACMI focuses

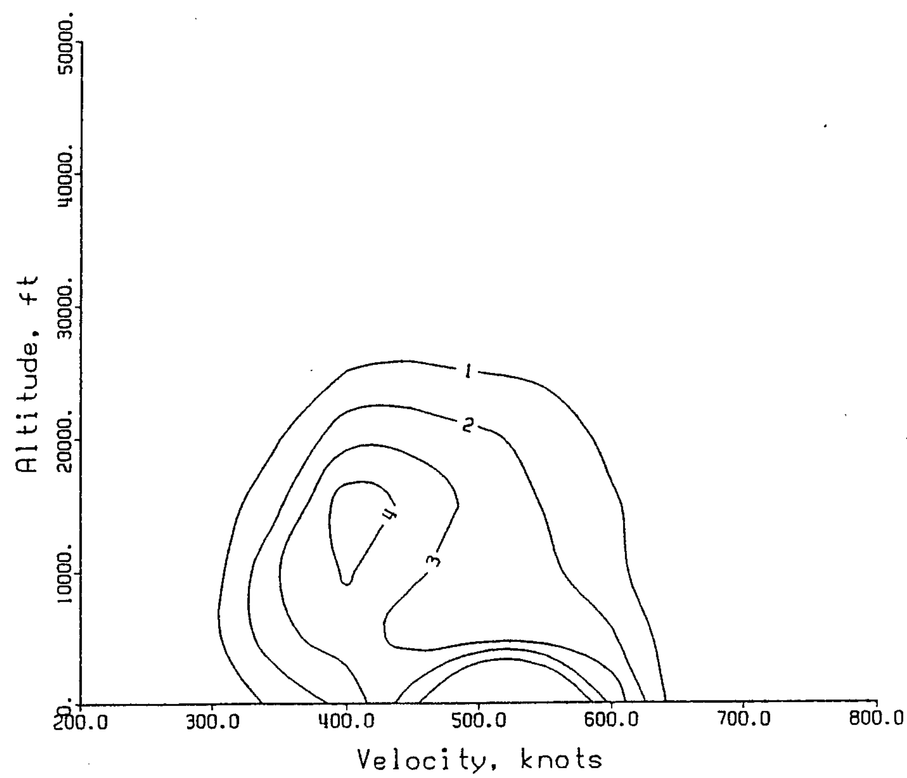


Figure 6. RFMDS F-16 Joint Altitude (AGL) / Speed Distribution.

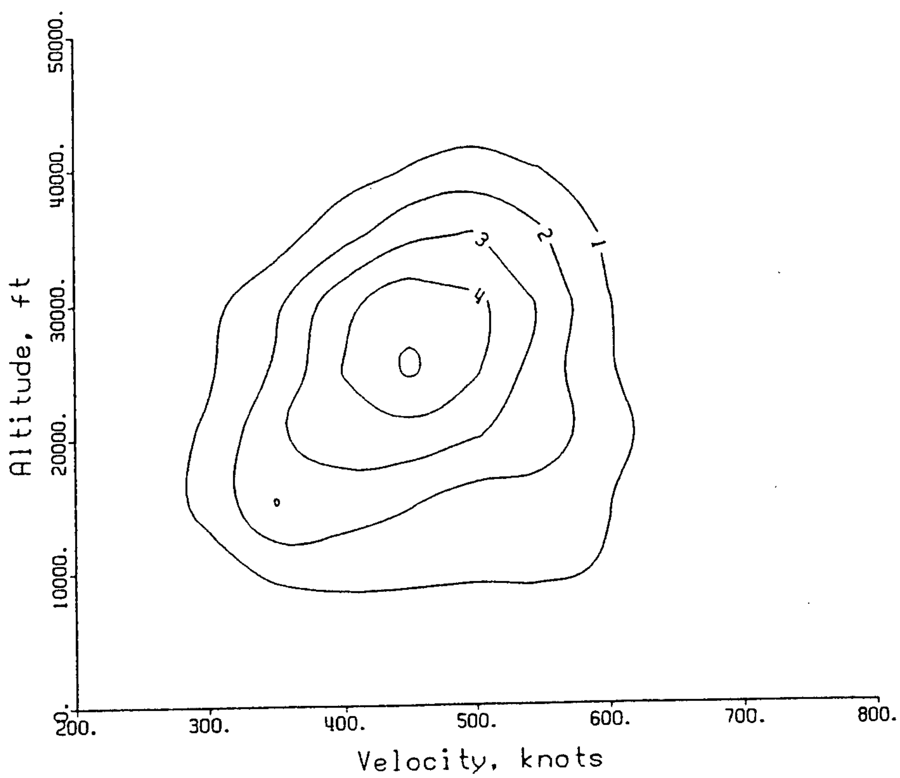


Figure 7. ACMI F-16 Joint Altitude (AGL) / Speed Distribution.

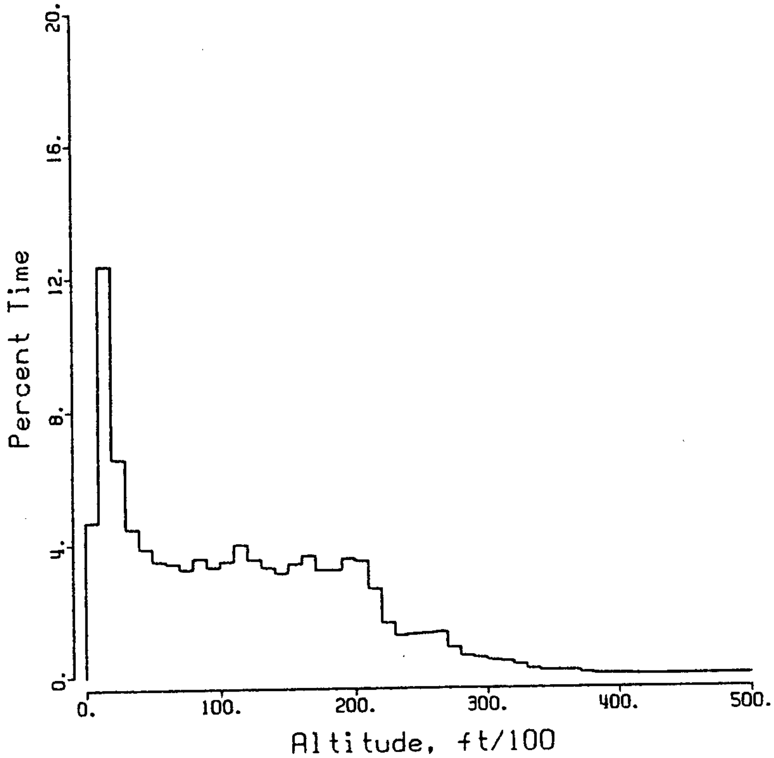


Figure 8. RFMDS F-16 Altitude Distribution, AGL.

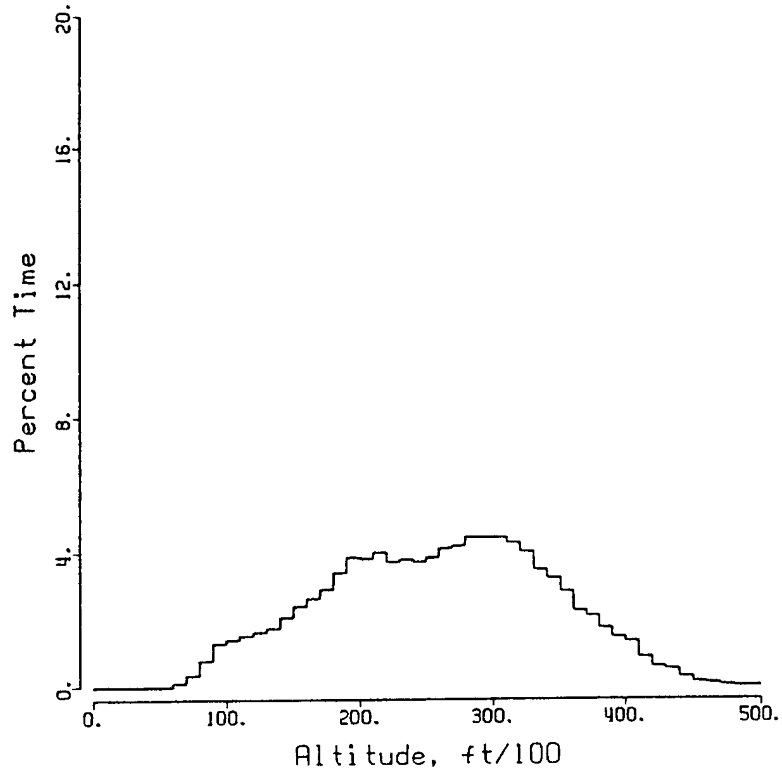


Figure 9. ACMI F-16 Altitude Distribution, AGL.

on air-to-air combat at high altitude and Red Flag missions simulate full-scale battle situations including low-altitude ground attack.

The remaining altitude distribution histograms may be found in Appendix A.

2.1.3 Operations Parameters on Military Training Routes

Three MTRs were investigated in this study. These included VR-1225, VR-1406, and IR-286. The parameters of these MTRs, including route width and floor, are listed in Table 1. It was estimated by personnel in the 57th FW scheduling office that aircraft on these MTRs spent 30 percent of the time between 100 feet AGL and 500 feet AGL (if the published MTR floor permitted) and the remaining 70 percent of the time between 500 feet AGL and 1,000 feet AGL. This estimated altitude distribution was used for MTR noise level modeling.

Table 1

MTR Parameters

MTR	Leg	Floor, Ft AGL	Width, nm
VR-1225	A–D	100	10
	D–E	100	8
	E–H	100	10
	H–I	500	10
VR-1406	A–J	SFC	10
IR-286	A–B	10,000 MSL	10
	B–D	500	10
	D–E	500	16
	E–M	SFC	10

2.2 Operations Scheduling

Two sources of schedule information were available for this analysis. The main source was the Range Group schedule data base. This provided as-flown scheduling for the entire Nellis Range Complex. The second source was the 57th FW. This provided schedule information for some of the Nellis Range but was itself contained in the Range Group data base. The 57th FW did, however, provide schedule information for three Military Training Routes (MTRs) associated with the Nellis Range that were not covered by the Range Group schedule.

2.2.1 Range Group Schedule

The Range Group Schedule contained information on operations throughout the Nellis Range Complex. The data base was organized chronologically by range subdivision. Each entry contained the date, start time, end time, user agency, range subdivision, mission type, number of aircraft, aircraft type, mission call sign, and other information.

Range Group Schedule data was obtained for the period of May 1990 through June 1991 and March 1992 through September 1992. As a worst-case scenario, the busiest month of the 1992 schedule period was selected for noise modeling. This occurred in April 1992.

Sorties listed in the Range Group schedule for April 1992 were counted for the three different operating arenas including the RFMDS arena, the ACMI arena, and all other range subdivisions. When counting the operations in the Range Group schedule, each mission was placed in one of the above operating arenas. This accounting scheme came as a result of the noise modeling method discussed later. The schedule information obtained from the Range Group schedule for April 1992 is listed in Table 2.

It is important to note that many operations conducted by F-117 aircraft were included in the Range Group schedule for April 1992 but not counted for noise modeling purposes. This was due to the fact that as of June 1992 the 57th TFW containing these aircraft has been relocated and no longer uses the Nellis Range Complex. It was determined, based on scheduling records before and after the relocation, that the absence of the 57th TFW did not alter the use of

Table 2

Range Group Schedule, April 1992

Aircraft	Operating Arena						TOTAL	
	RFMDS		ACMI		Others			
	Day	Night	Day	Night	Day	Night	Day	Night
F-111	56	0	0	0	0	0	56	0
F-18	275	8	153	0	2	0	430	8
F-16	325	28	524	12	417	22	1,266	62
F-15	449	32	322	4	146	6	917	42
F-14	55	8	0	0	14	0	69	8
F-5	12	2	0	0	0	0	12	2
F-4	84	0	2	0	3	0	89	0
A-10	40	0	4	0	223	0	267	0
A-6	38	8	20	0	8	0	66	8
B-2	0	9	0	0	0	9	0	18
Other	50	3	12	0	0	0	62	3
TOTAL	1,384	98	1,037	16	813	37	3,234	151

the Nellis Range Complex by other users. In any event, the number of operations conducted by all other aircraft during April 1992 still represents the month with the greatest number of operations. Therefore the schedule information based on the April 1992 Range Group data serves as a worst-case scenario for noise calculations.

2.2.2 57th Fighter Wing Schedule

The schedule information from the 57th FW contained information for June 1990 through May 1991. The information included aircraft type and numbers of monthly sorties. This data covered some parts of the Nellis Range Complex and three MTRs. That part of the schedule covering the Nellis Range was duplicated in the Range Group schedule. The information on the two MTRs was unique.

The three MTRs included in the 57th FW schedule were VR-1225, VR-1406, and IR-286. As a worst-case scenario, the month with the highest number of operations was selected from the schedule for noise modeling. These were October 1990 for VR-1225 and VR-1406, and November 1990 for IR-286. The operations information is listed in Table 3.

Table 3

57th Fighter Wing MTR Schedule,
Busiest Month

Aircraft	Monthly Operations		
	VR-1225	IR-286	VR-1406
F-111	4	4	1
F-18	0	4	0
F-16	24	2	0
F-15	48	9	2
AV-8	1	0	0
A-7	1	0	1
T-38	0	3	0

2.3 Noise Modeling

The noise modeling for the Nellis AFB airspaces was divided into four separate analysis areas. These were the range subdivisions covered by the RFMDS operations, the range subdivisions covered by ACMI operations, all other range subdivisions, and the three MTRs. The process for modeling the noise environment in each of these areas is discussed separately.

2.3.1 Noise Modeling in the RFMDS Arena

The basis for modeling noise in the RFMDS arena consisted of the RFMDS flight data discussed previously and currently existing USAF ROUTEMAP/NOISEMAP technology. The RFMDS data base provided a statistical model of operations. This operations model was then used as input to the ROUTEMAP/NOISEMAP noise modeling techniques to calculate the noise environment.

The first step toward modeling the noise environment was to construct a statistical operations model. This involved constructing a three-dimensional grid which covered the extent of the Nellis Range Complex in 25-square-mile blocks and reached from the surface to 50,000 feet MSL. As in the spatial and altitude distributions before, each sortie in the RFMDS tracking data was followed and the time spent in each of these 5-mile by 5-mile by 500-foot-high grid blocks was accumulated. This process was carried out independently for each type of aircraft in the data base.

The three-dimensional grid is essentially a combination of the normalized time on range graphics shown in Figures 4 and 5 and the altitude distributions shown in Figures 8 and 9. This cumulative grid represented the amount of time the different types of aircraft spent over each part of the range complex and at what altitude. This provided the statistical operations models necessary for the noise calculations.

As shown in Figure 4, the RFMDS operations do not cover the entire Nellis Range Complex. These operations utilize only those range subdivisions in the RFMDS arena listed in Section 1 and shaded in Figure 1. For this reason, the operations model constructed from the RFMDS tracking data base was only used to model the noise environment in those range subdivisions.

The operations models obtained from the Red Flag 92-4 data base were selected as the model for noise calculations. This set of models was selected as a worst-case scenario. It was determined that the operations of this Red Flag mission would create the loudest noise environment of the three RFMDS data sets.

The next step toward calculating the noise environment was to determine the actual number of operations within the RFMDS arena. This information was provided by the Range Group Schedule information discussed previously and listed in Table 2. It was assumed that all operations conducted in the RFMDS arena followed the RFMDS-based models.

Those aircraft types listed in the Range Group schedule which corresponded directly to aircraft types in the RFMDS data base were assumed to operate according to the operations model developed for that aircraft. The operations models were scaled to appropriately reflect the actual number of operations indicated by the Range Group schedule. All aircraft operations from the Range Group schedule which did not match one of the aircraft types from the RFMDS data base were modeled as F-15s. The majority of these unmatched aircraft were F-18s which are most like the F-15 in noise footprint.

The final step in modeling the noise environment was to calculate the noise levels associated with the Range Group operations based on the RFMDS operations models. This was accomplished by using the USAF ROUTEMAP/NOISEMAP technology.

The acoustical energy associated with an aircraft overflight was obtained from ROUTEMAP. This energy was then scaled according to the time all aircraft spent in an area. The total acoustical energy was then uniformly distributed over the area. This is equivalent to assuming that aircraft operations are uniformly distributed throughout the area.

This approach was used to calculate the noise level associated with each aircraft type for each of the grid blocks in the three-dimensional operations model grid. The noise level associated with each of the grid blocks was totalled over the entire RFMDS arena. These noise levels represent the expected Day/Night Average Sound Level for each 5-mile by 5-mile block over all of the range subdivisions in the RFMDS arena. The results of these calculations are presented in Section 3.1.

2.3.2 Noise Modeling in the ACMI Arena

Noise modeling of high-altitude ACM operations in the ACMI arena, which included the Elgin and Caliente MOAs, was conducted similarly to the modeling done in the RFMDS arena. The only difference was the basis of the operations model and the number of operations. The operations models for the ACMI arena were based on the ACMI data base discussed earlier. The number of operations to which the ACMI operations model was scaled was based on the those operations in the Elgin MOA which conducted high-altitude ACM missions. The operations in the ACMI arena which did not fall under ACM types of operations were modeled in a different way.

Since no information was available on the altitude and spatial distributions of non-ACM operations in the Elgin MOA, some assumptions were made. First, it was assumed that these non-ACM operations flew according to the altitude distributions calculated for the RFMDS operations. The second assumption was that the operations were uniformly distributed within the Elgin MOA. This made the noise levels due to these operations a function of aircraft type, altitude of operation, and the time spent in the MOA. The time spent in the airspace was assumed to be 45 minutes. This was the average time spent on range by the aircraft in the RFMDS data.

The USAF ROUTEMAP/NOISEMAP computer program was used to model the noise environment in a manner similar to that described in Section 2.3.1. The results of these calculations are presented in Section 3.1.

2.3.3 Noise Modeling in Other Areas of the Nellis Range

There are seven range subdivisions in the Nellis Range Complex that were not covered by the RFMDS or ACMI flight data systems. These subdivisions included R-61, R-62, R-63, R-64, R-65, Alamo, and R-4808 East. Since no operations information was available on which to base an operations model, the altitude of operations and the time on range had to be assumed. The altitude distributions obtained from the RFMDS data were applied to these operations. In addition, it was assumed that the operations were uniformly distributed throughout these airspaces. The time spent within the airspace was again assumed to be 45 minutes, the average time spent on range by the aircraft in the RFMDS tracking data.

Once again, the USAF ROUTEMAP/NOISEMAP computer program was used to model the noise environment as described in Section 2.3.1. This made the noise calculations a function of aircraft type, altitude of operation, and time on range. The results of these calculations are presented in Section 3.1.

2.3.4 Noise Modeling Along Military Training Routes

The noise environment under the three MTRs was modeled using the USAF ROUTEMAP program. The number of operations were determined from the 57th FW schedule as discussed previously. The ROUTEMAP program assumes that the operations along an MTR have a Gaussian lateral distribution about the route centerline. The standard deviation of this distribution is equal to 0.18 times the width of the MTR. The results of these calculations are presented in Section 3.2.

3.0 THE NOISE ENVIRONMENT

An assessment of aircraft noise requires a general understanding of how sound is measured and its effects on people and things. Appendix B provides a detailed discussion of noise and its effects on the environment. The descriptions that follow assume a knowledge of the noise metrics and compatibility guidelines discussed in Appendix B.

3.1 Noise Levels in the Nellis Range Complex

The noise levels for all areas of the Nellis range were compiled into a composite grid. There were four distinct noise level grids which contributed to the composite grid. These included the RFMDS based noise model which covered the RFMDS arena, the ACMI based noise model which included ACM missions in the ACMI arena, the non-ACM operations in the Elgin MOA, and operations in all other range subdivisions. Contours of Day/Night Average Sound Level for the composite grid are shown in Figure 10.

The maximum Day/Night Average Sound Level calculated for the Nellis Range is 65 dB. This level occurs in the 25-square-mile grid bin centered 35 miles northeast of the RFMDS coordinate center. The land under this area is uninhabited desert plains and mountains. This noise level is acceptable for this type of land use, as described in Appendix B. Day/Night Average Sound Levels throughout the rest of the range are less than 65 dB and are therefore acceptable for all land uses.

3.2 Noise Levels Under Military Training Routes

The Rate-Adjusted Day/Night Average Sound Levels for the three MTRs are listed in Table 4. Included in Table 4 are the levels for each leg of the MTRs at various lateral distances from the route centerline. These levels reflect the estimated altitude distribution and MTR parameters discussed previously.

The loudest segment of VR-1225 is from points A through H and has a noise level of 62 dB under the route centerline. The entire route of VR-1406 experiences a noise level of 48 dB under the centerline. Points E through M on IR-286 have the greatest noise level under the centerline of 55 dB. In each case, the maximum Rate Adjusted Day/Night Average Sound Level is well within acceptable land-use compatibility guidelines.

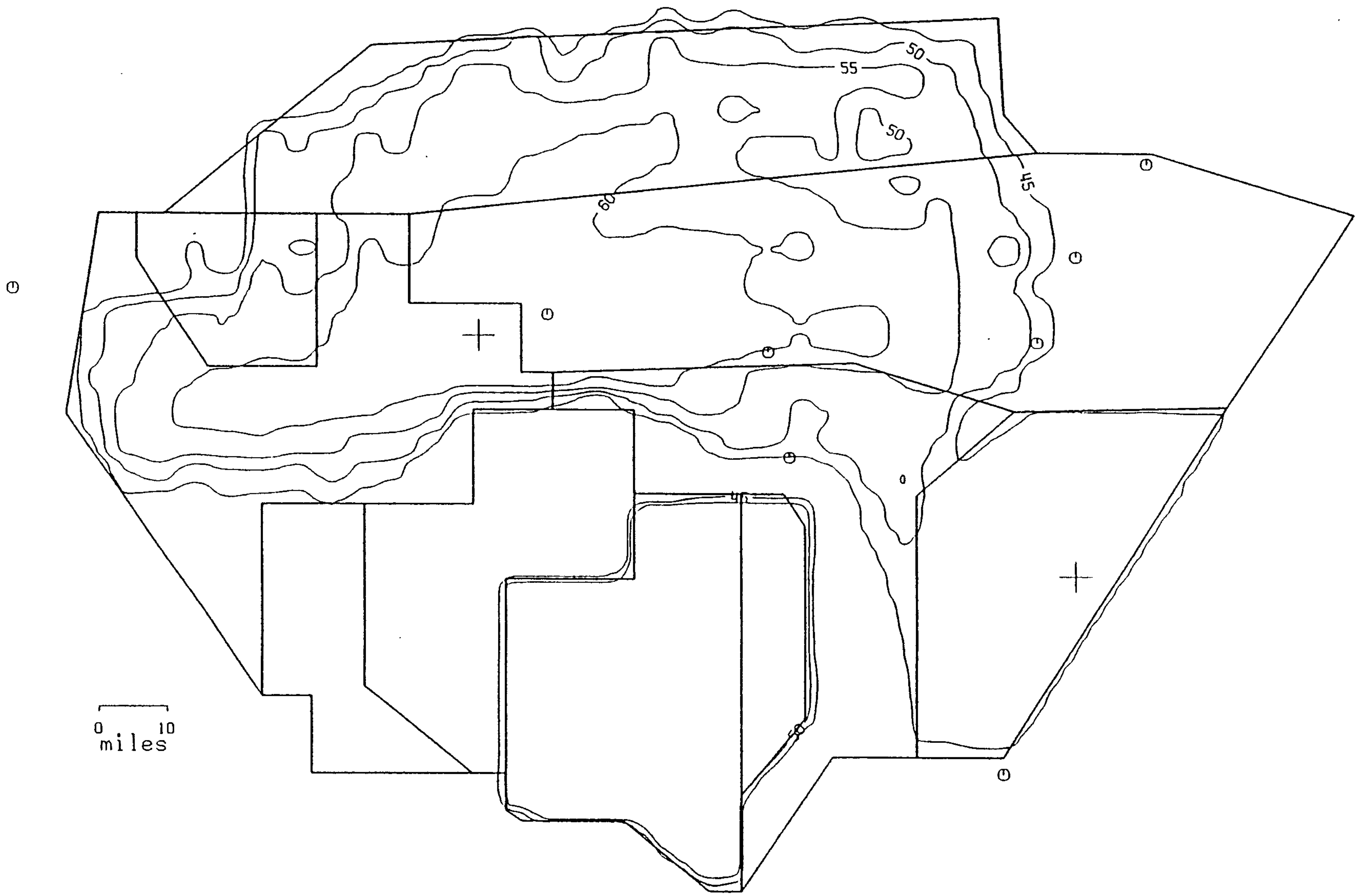


Figure 10. Composite L_{dn} Contours for the Nellis Range Complex.

Table 4

MTR Noise Levels

MTR	Leg	Sound Level for Various Lateral Distances, dB				
		0 Ft	5,000 Ft	10,000 Ft	15,000 Ft	20,000 Ft
VR-1225	A–D	62	61	59	57	53
	D–E	62	61	59	57	53
	E–H	62	61	59	57	53
	H–I	61	60	58	56	52
VR-1406	A–J	48	48	46	44	40
IR-286	A–B	27	27	26	25	24
	B–D	54	54	52	49	46
	D–E	52	52	51	50	49
	E–M	55	55	53	50	47

4.0 CONCLUSIONS

The noise levels under the Nellis Range Complex and two MTRs have been calculated. The process of modeling the noise levels consisted of modeling the operations in the range based on RFMDS and ACMI data bases and scaling these models to the number of operations reported in the busiest month of 1992 according to the Range Group scheduling data base. The noise levels for the Nellis Range Complex are presented in the form of composite contours. In the case of the three MTRs the noise levels for various lateral distances from the MTR centerline are reported.

It was found that, in all airspaces, the Day/Night Average Sound Levels were within normally acceptable land-use compatibility guidelines.

APPENDIX A

Analysis Results for RFMDS Tracking Data
Covering Red Flag 92-4 and ACMI Tracking Data
Covering 1 April 1992 Through 31 September 1992

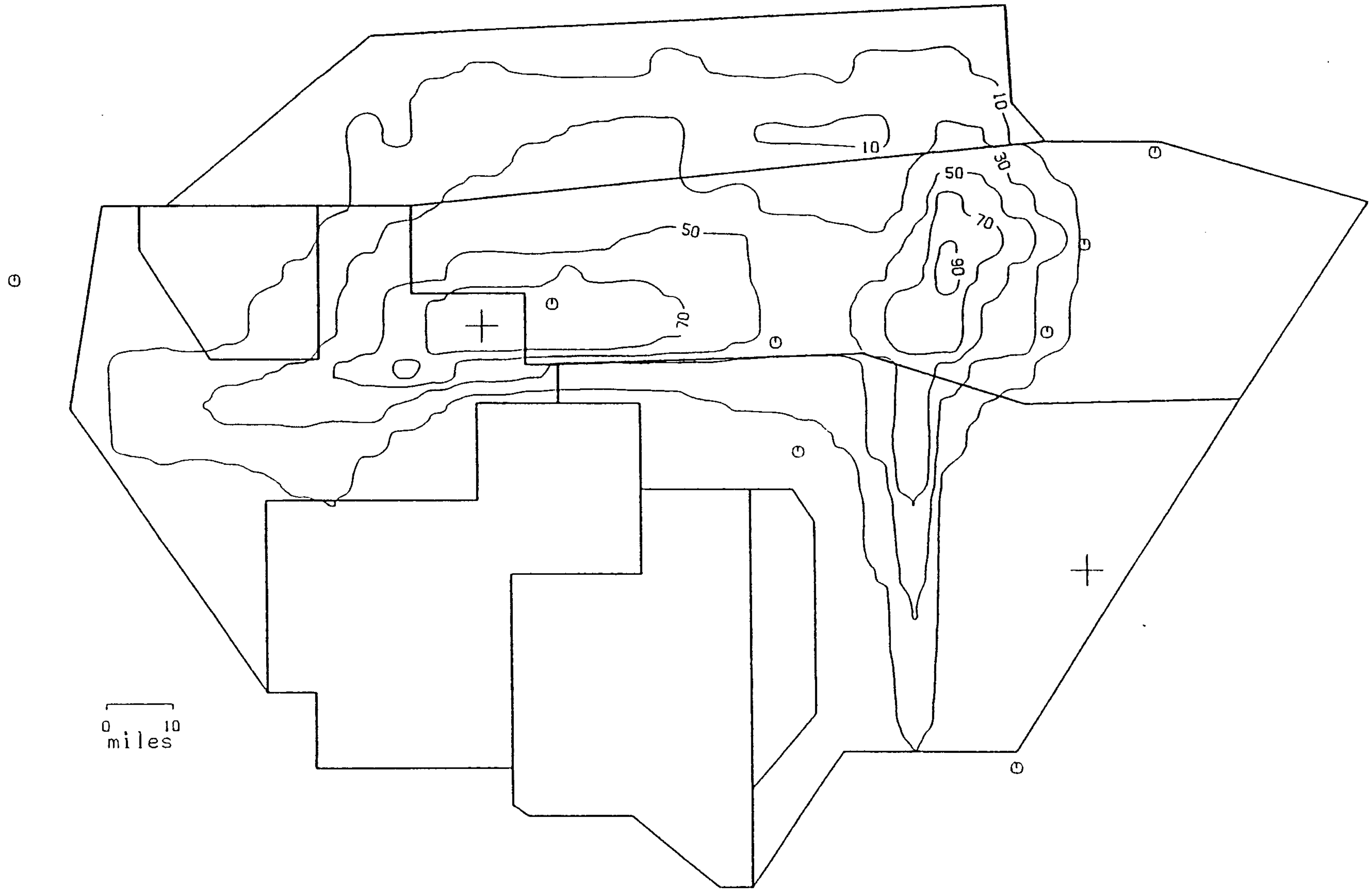


Figure A1. F-15 Red Flag 92-4 Normalized Time on Range.

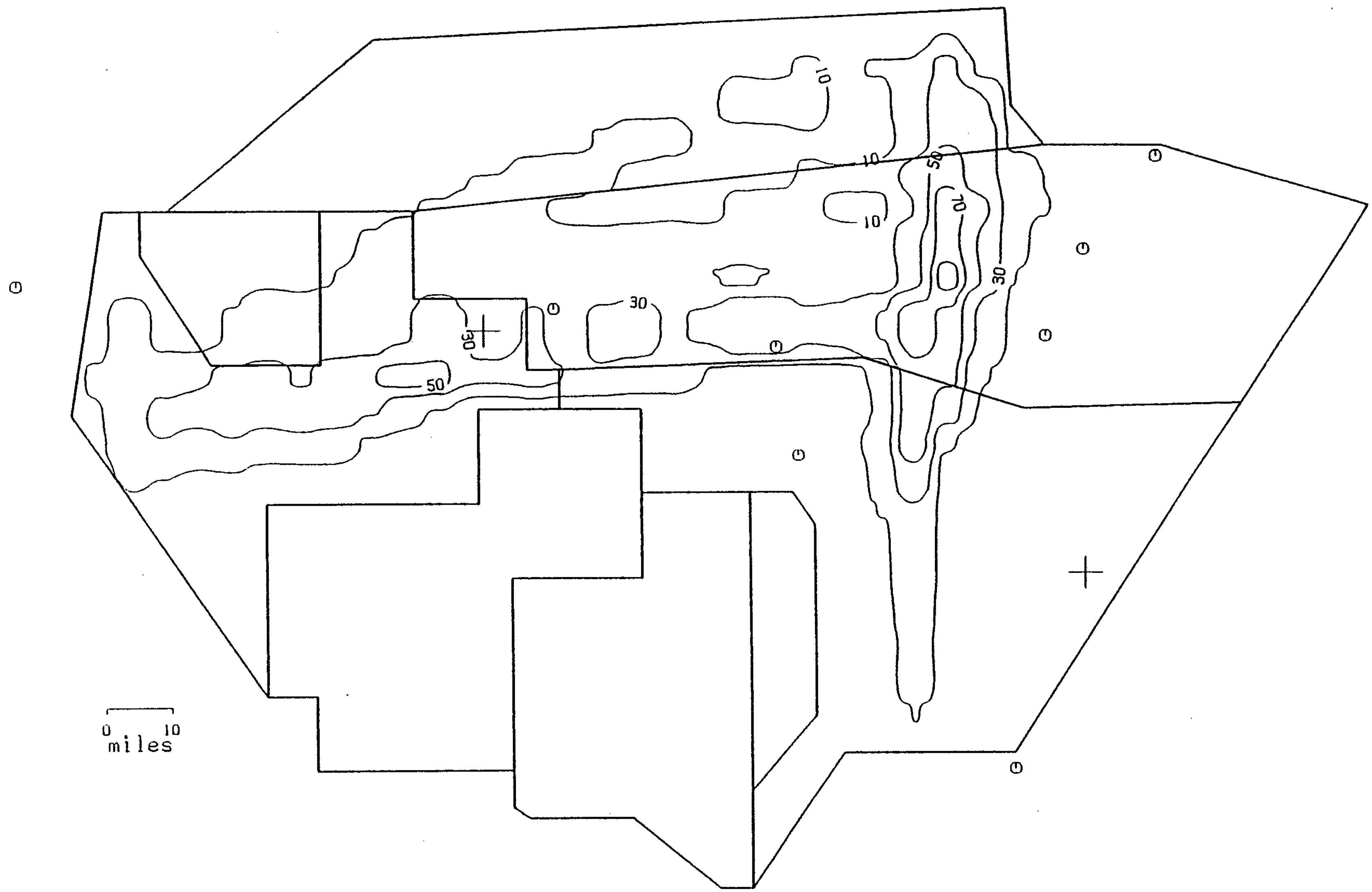


Figure A2. F-111 Red Flag 92-4 Normalized Time on Range.

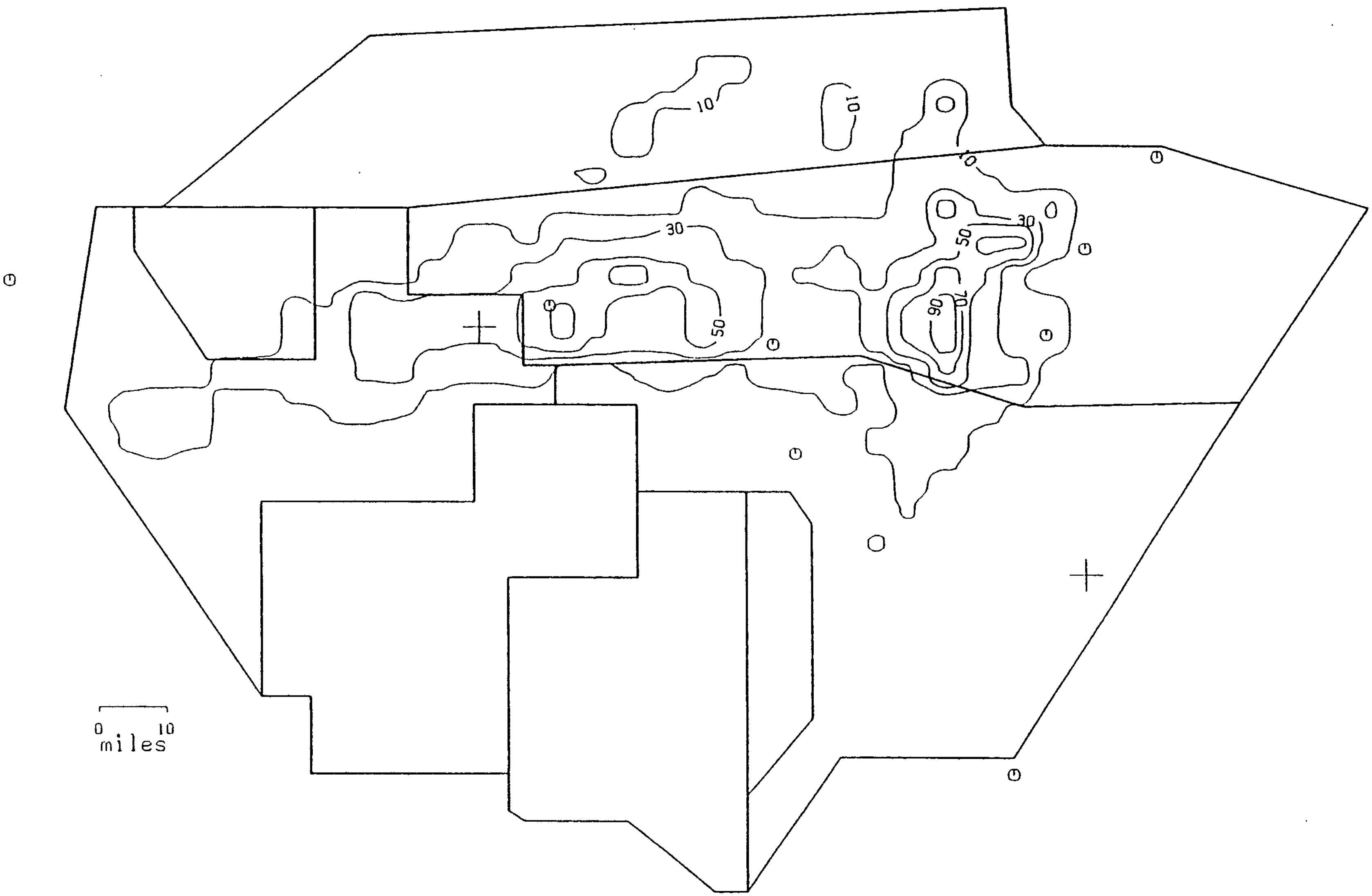


Figure A3. F-4 Red Flag 92-4 Normalized Time on Range.

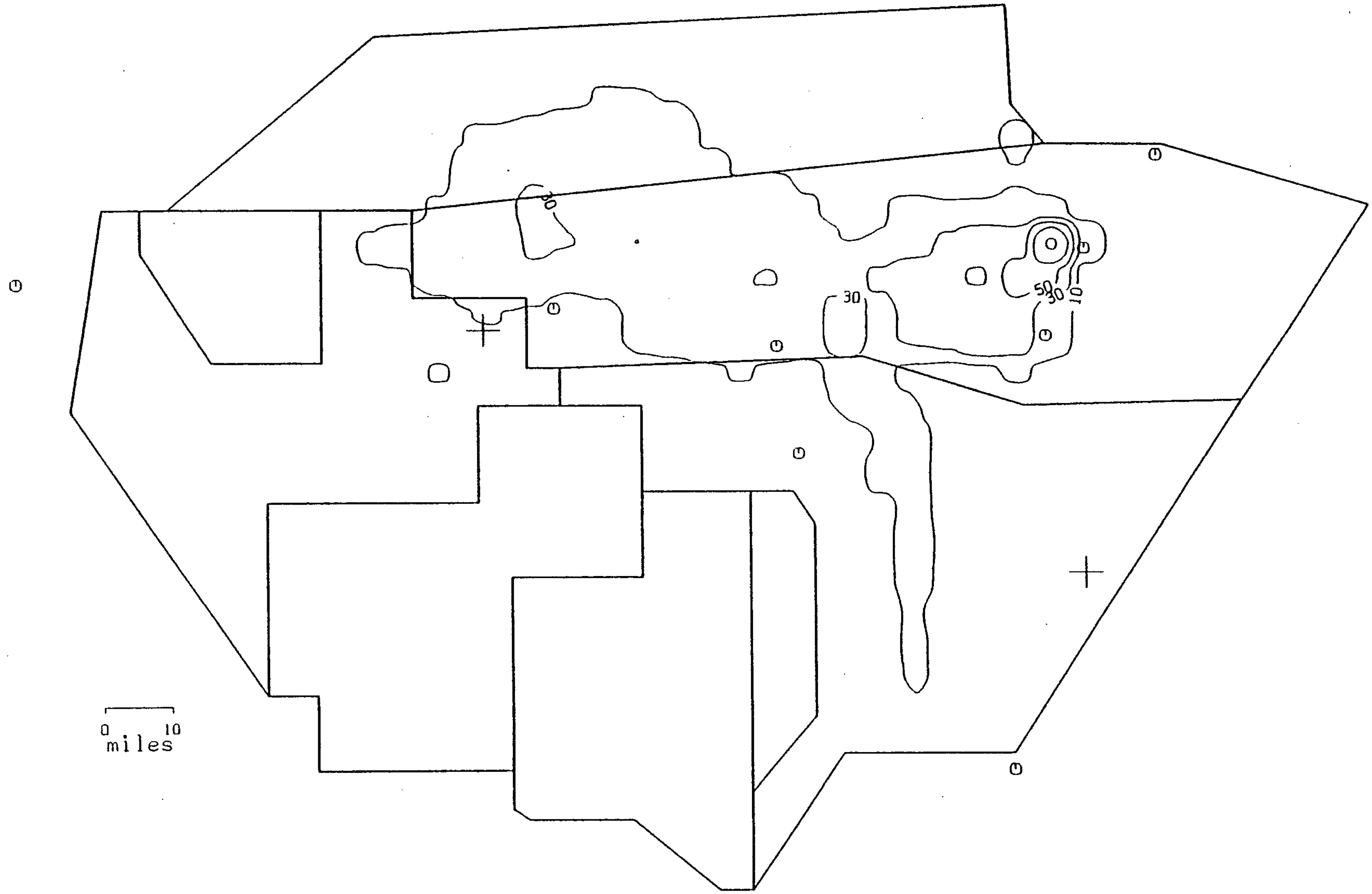


Figure A4. F-4E Red Flag 92-4 Normalized Time on Range.

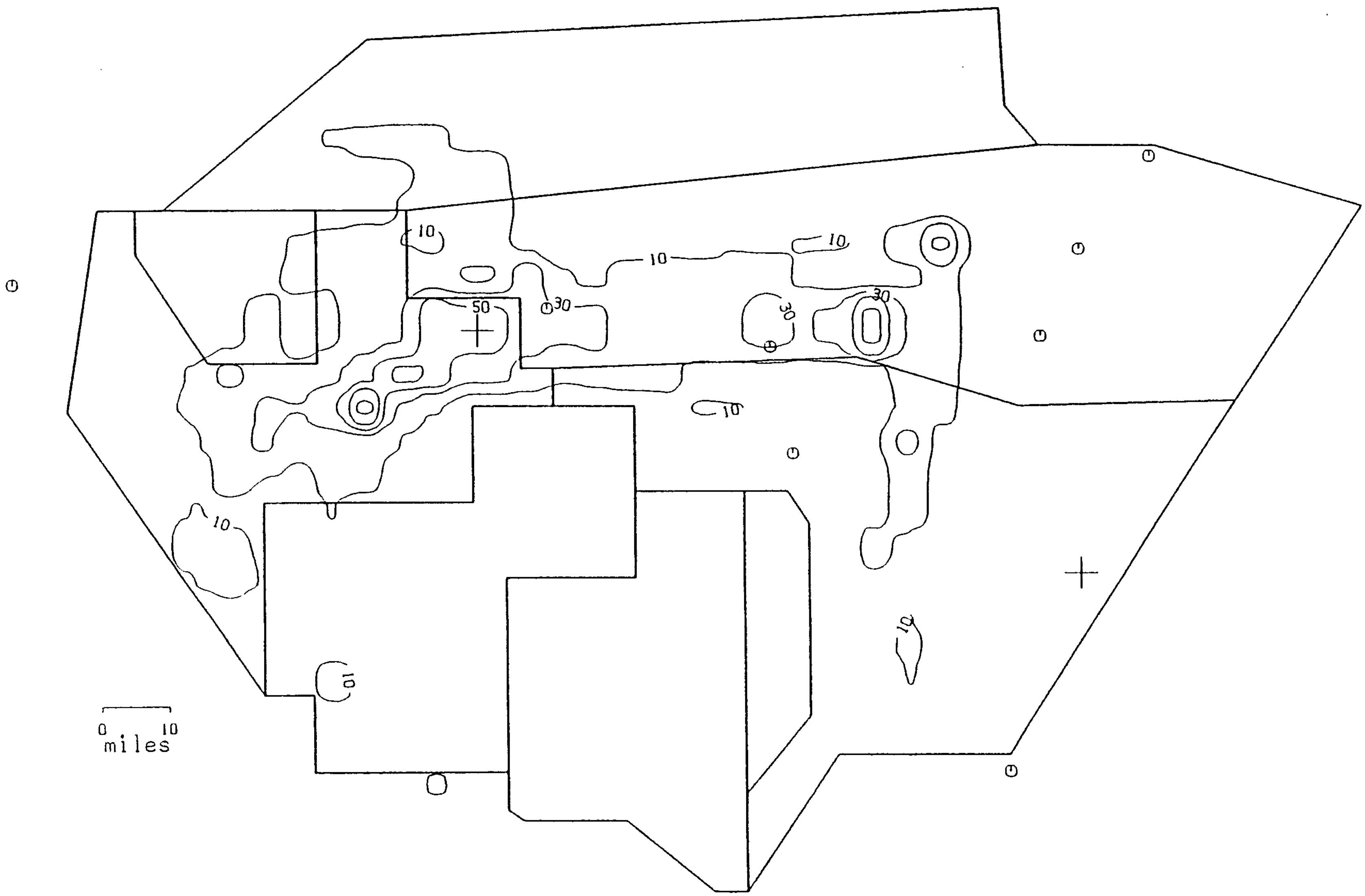


Figure A5. B-52 Red Flag 92-4 Normalized Time on Range.

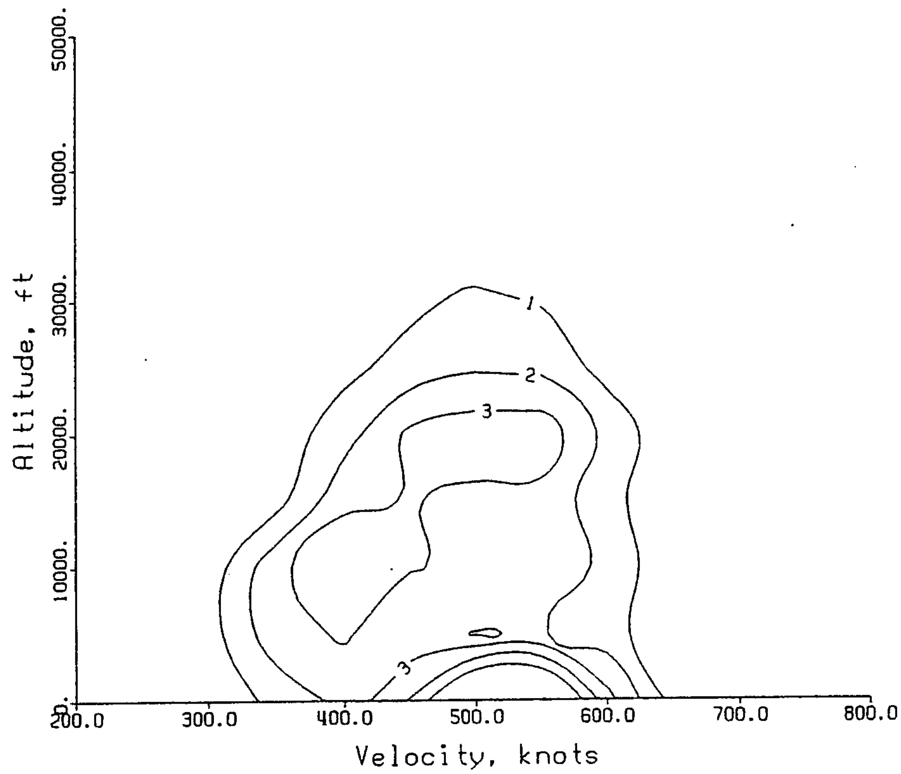


Figure A6. F-15 Red Flag 92-4 Altitude (AGL) / Speed Distribution.

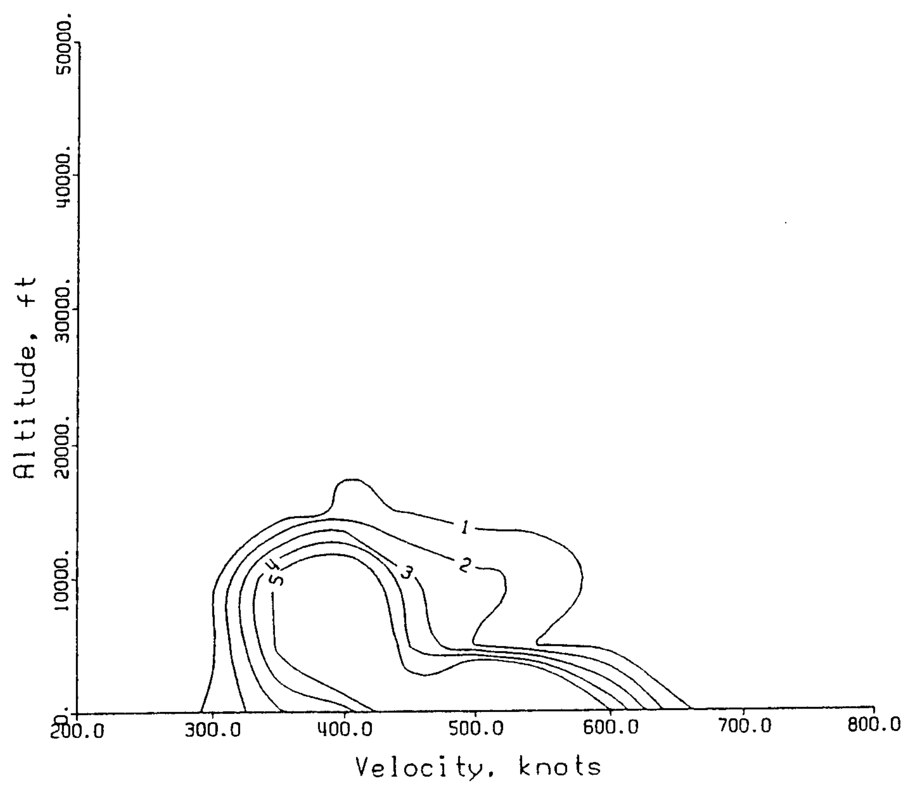


Figure A7. F-111 Red Flag 92-4 Altitude (AGL) / Speed Distribution.

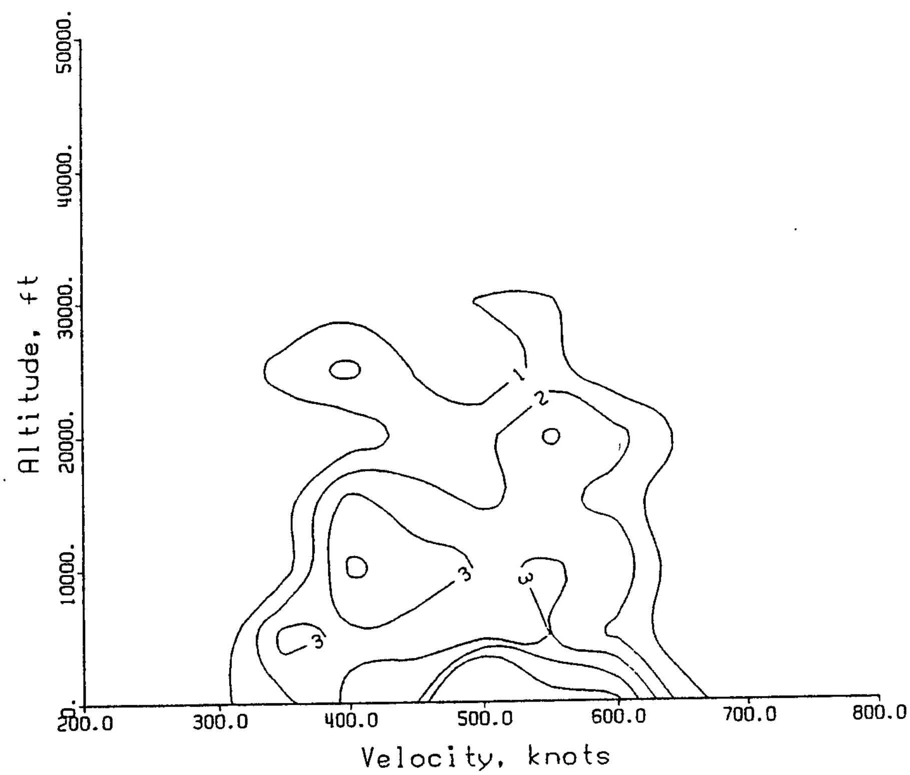


Figure A8. F-4 Red Flag 92-4 Altitude (AGL) / Speed Distribution.

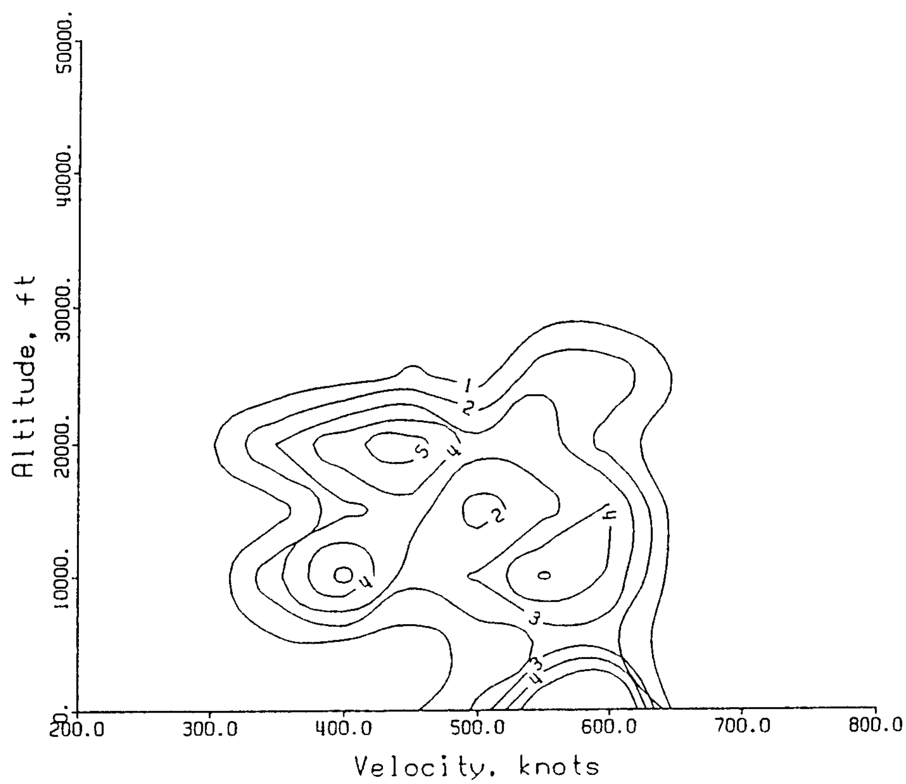


Figure A9. F-4E Red Flag 92-4 Altitude (AGL) / Speed Distribution.

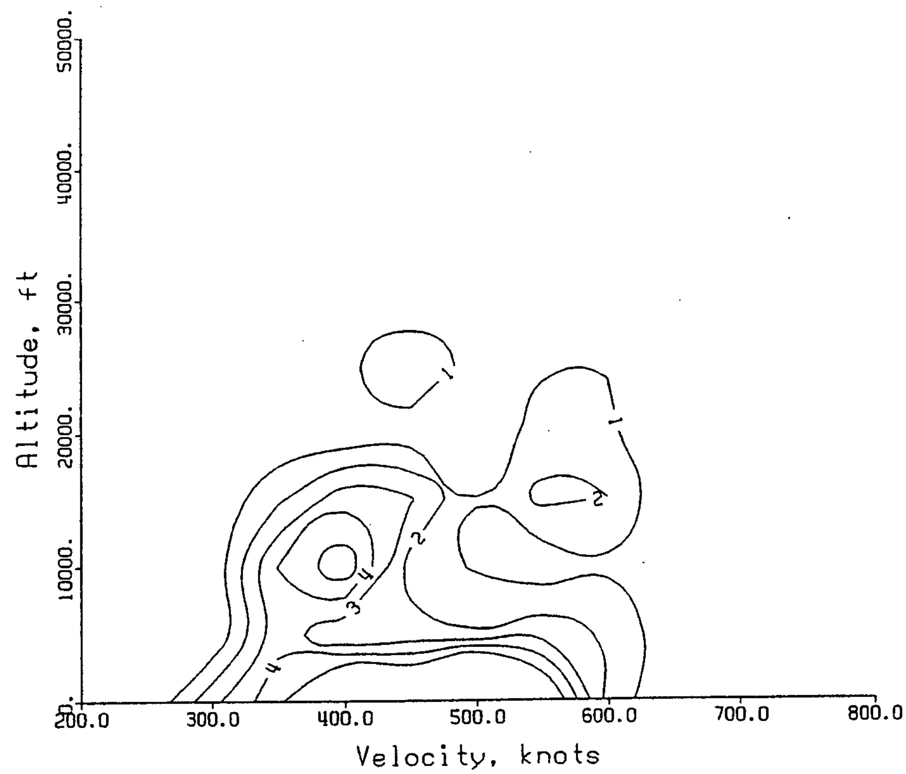


Figure A10. B-52 Red Flag 92-4 Altitude (AGL) / Speed Distribution.

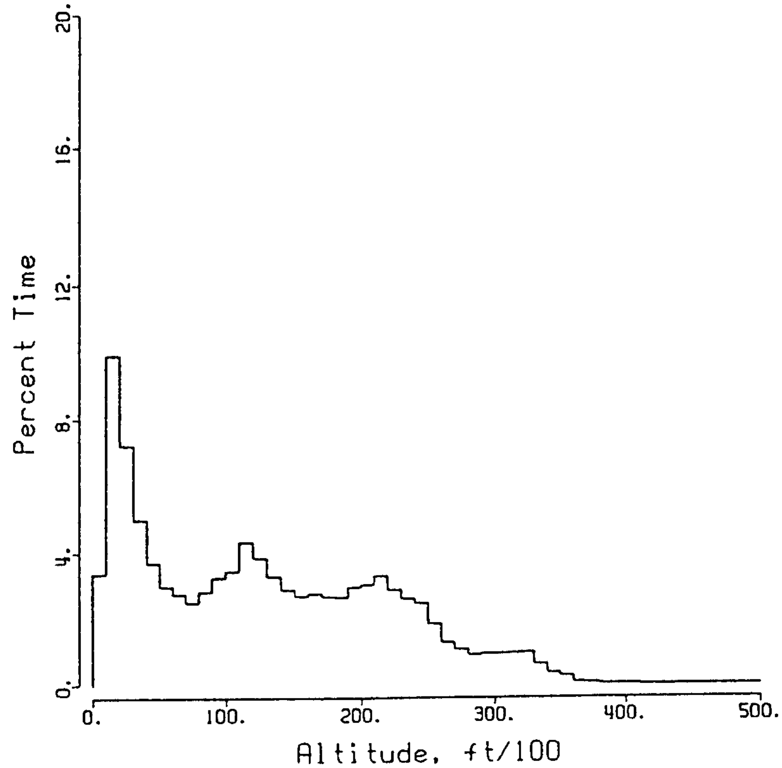


Figure A11. F-15 Red Flag 92-4 Altitude Distribution, AGL.

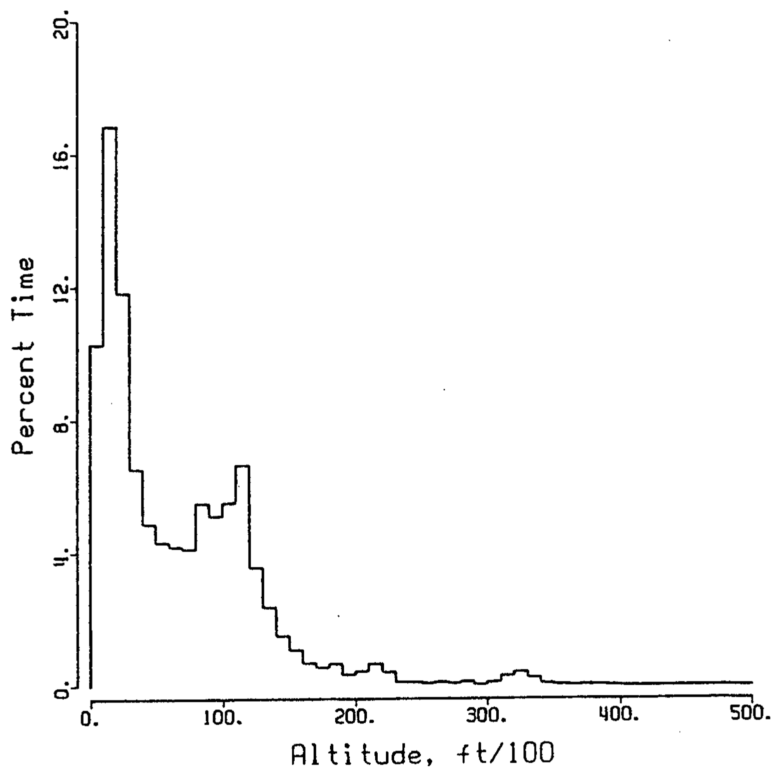


Figure A12. F-111 Red Flag 92-4 Altitude Distribution, AGL.

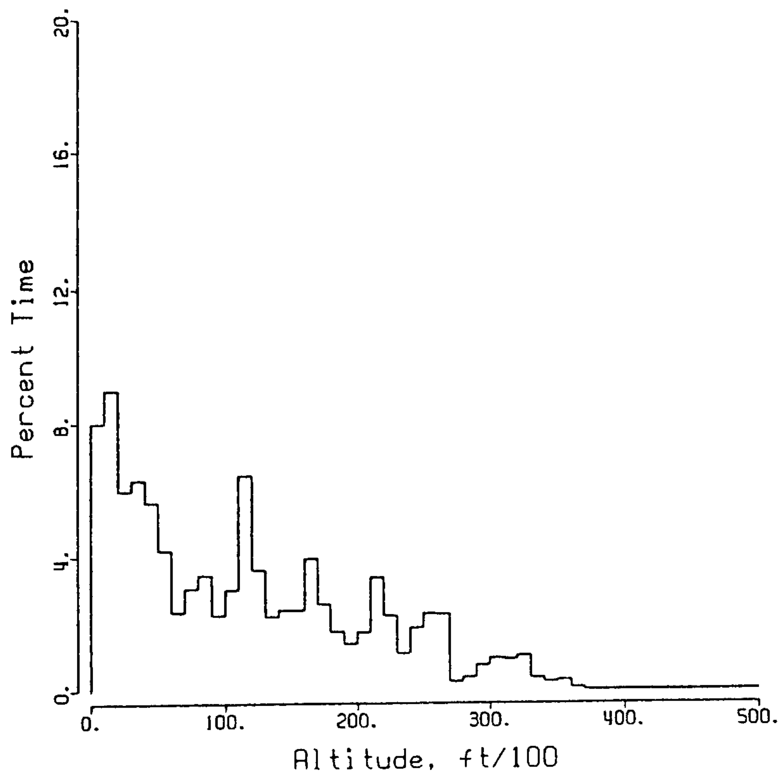


Figure A13. F-4 Red Flag 92-4 Altitude Distribution, AGL.

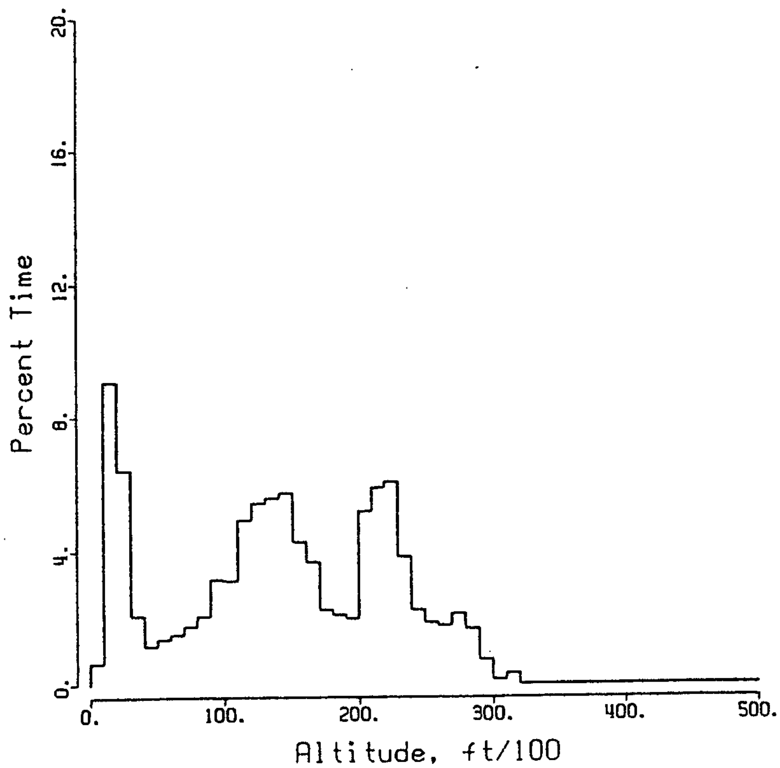


Figure A14. F-4E Red Flag 92-4 Altitude Distribution, AGL.

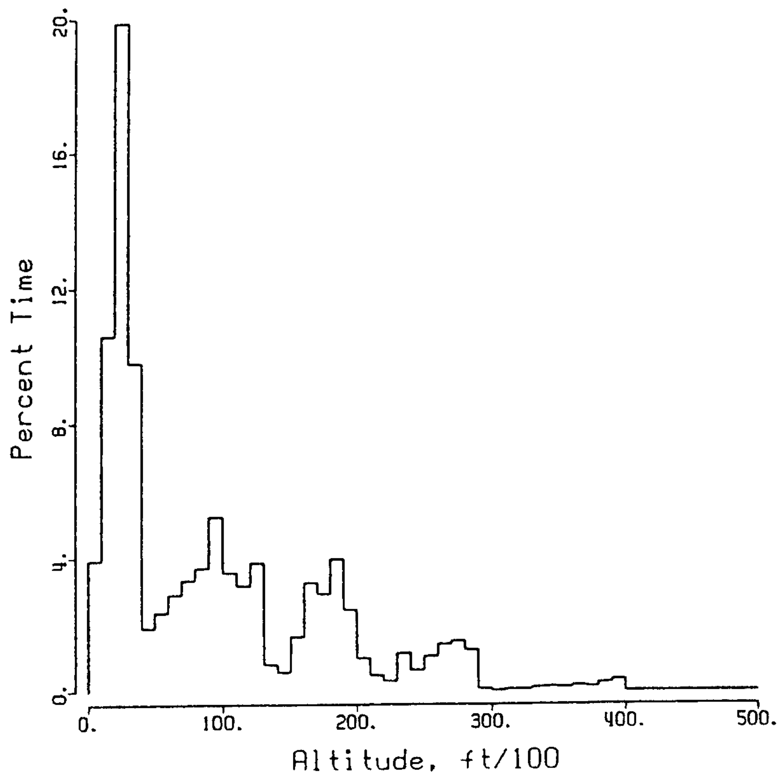


Figure A15. B-52 Red Flag 92-4 Altitude Distribution, AGL.

Figure A16. F-15 ACMI Normalized Time on Range.

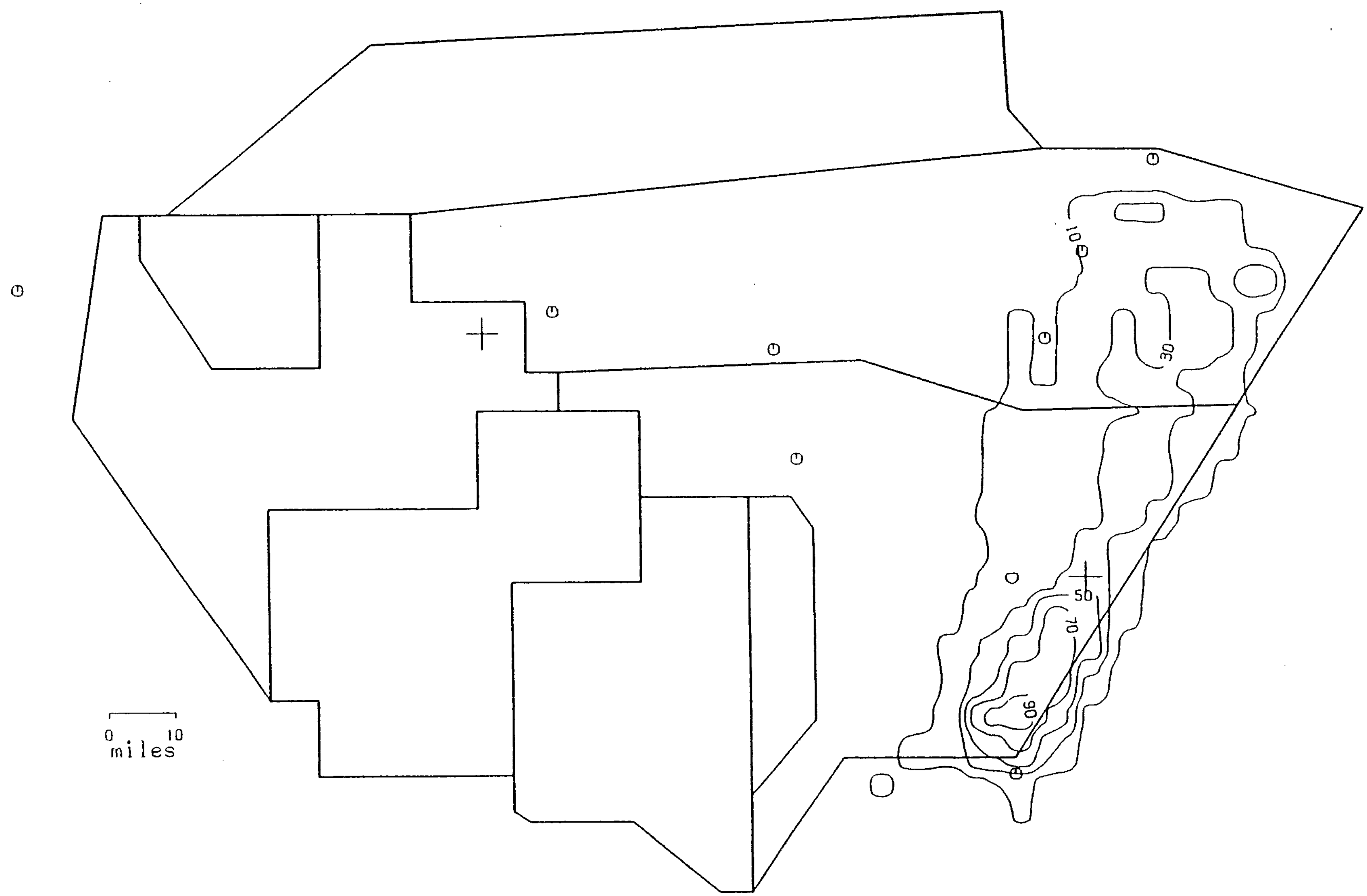


Figure A17. F-18 ACMI Normalized Time on Range.

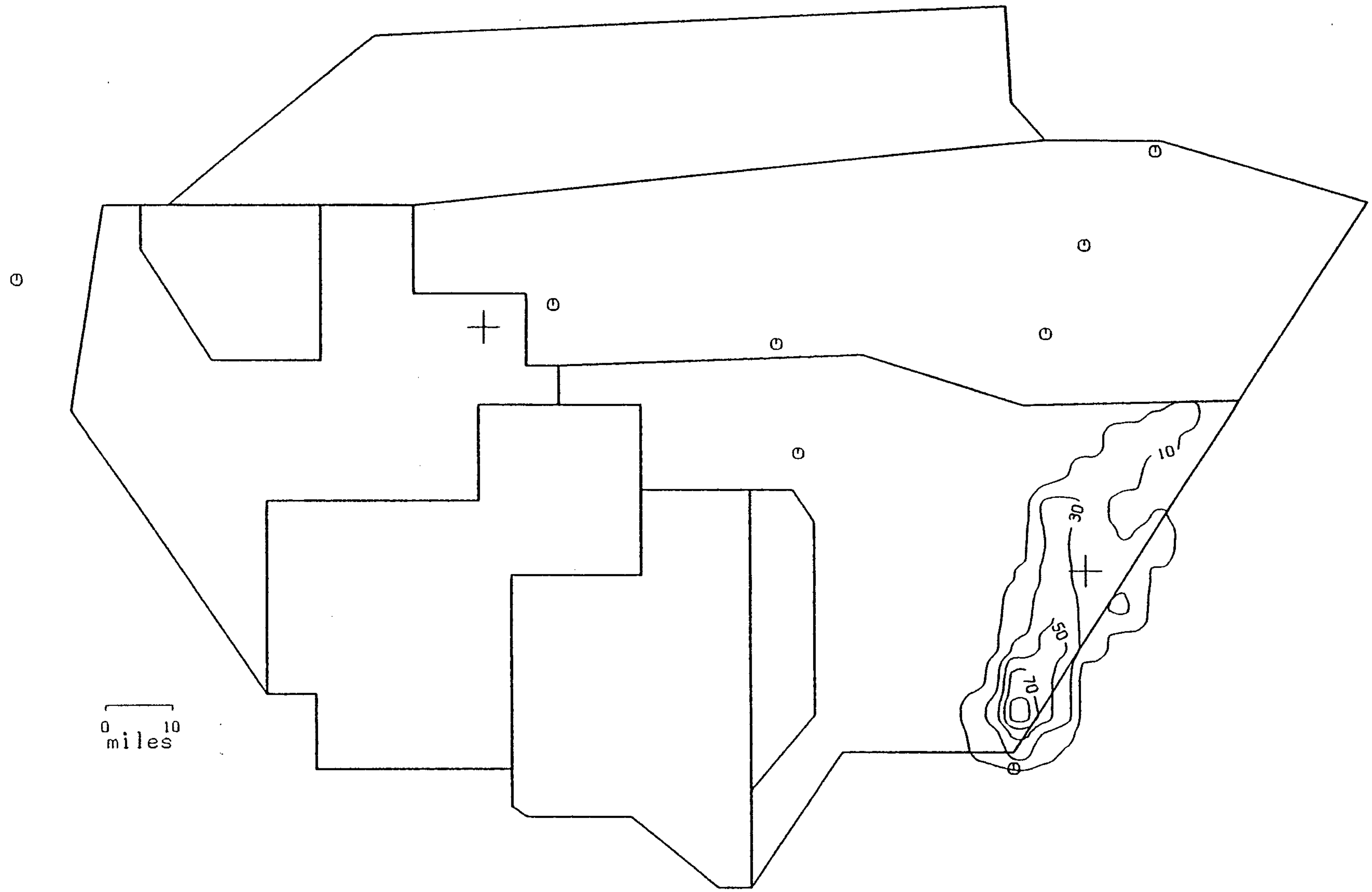


Figure A18. A-10 ACMI Normalized Time on Range.

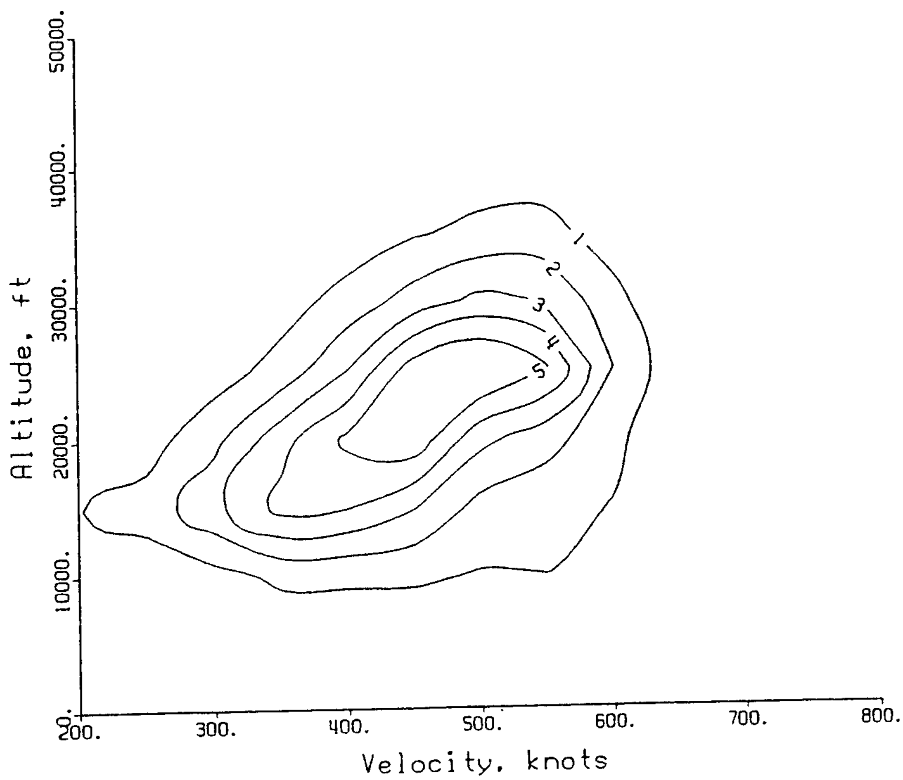


Figure A19. F-15 ACMI Altitude/Speed Distribution.

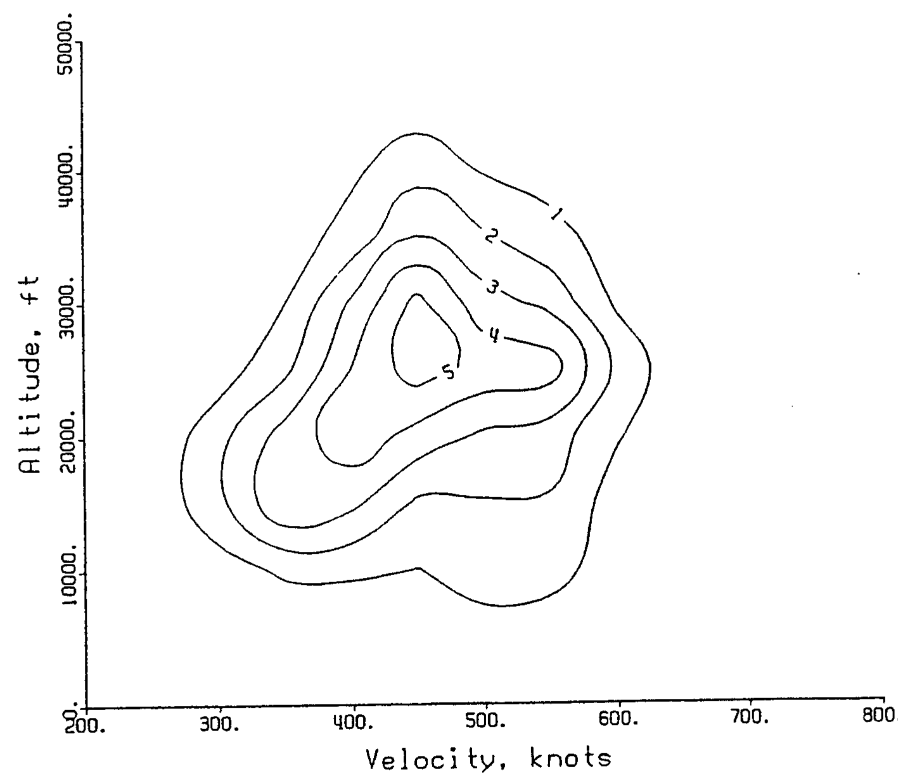


Figure A20. F-18 ACMI Altitude/Speed Distribution.

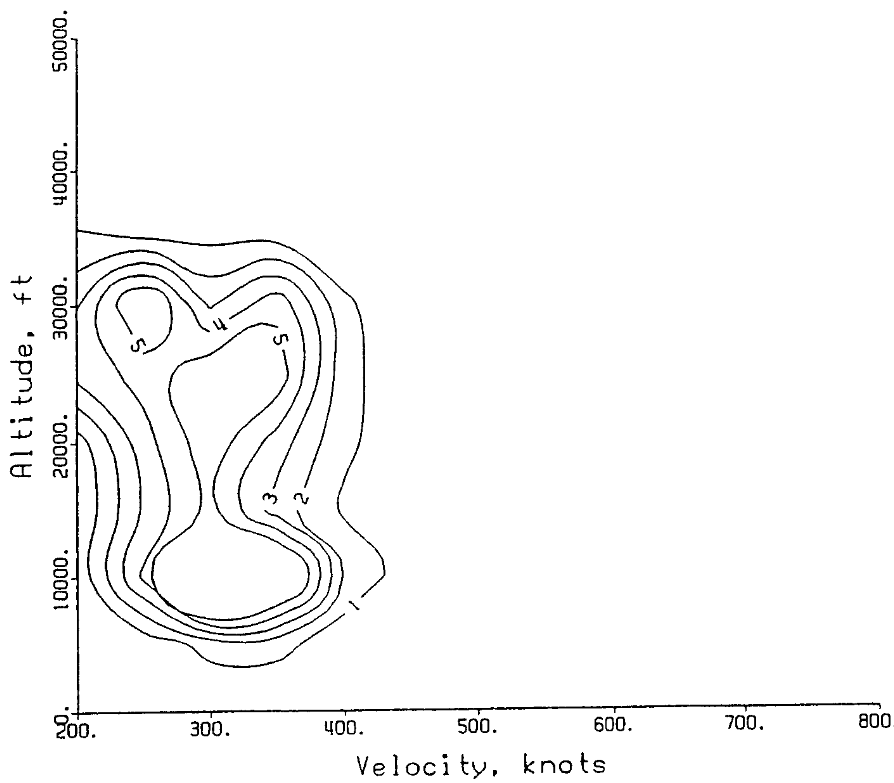


Figure A21. A-10 ACMI Altitude/Speed Distribution.

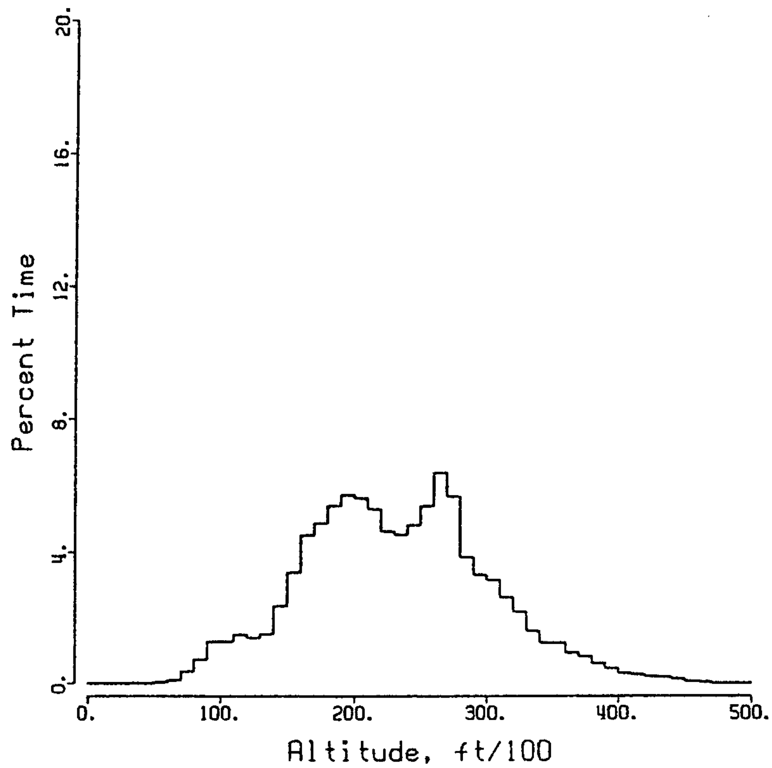


Figure A22. F-15 ACMI AGL Altitude Distribution.

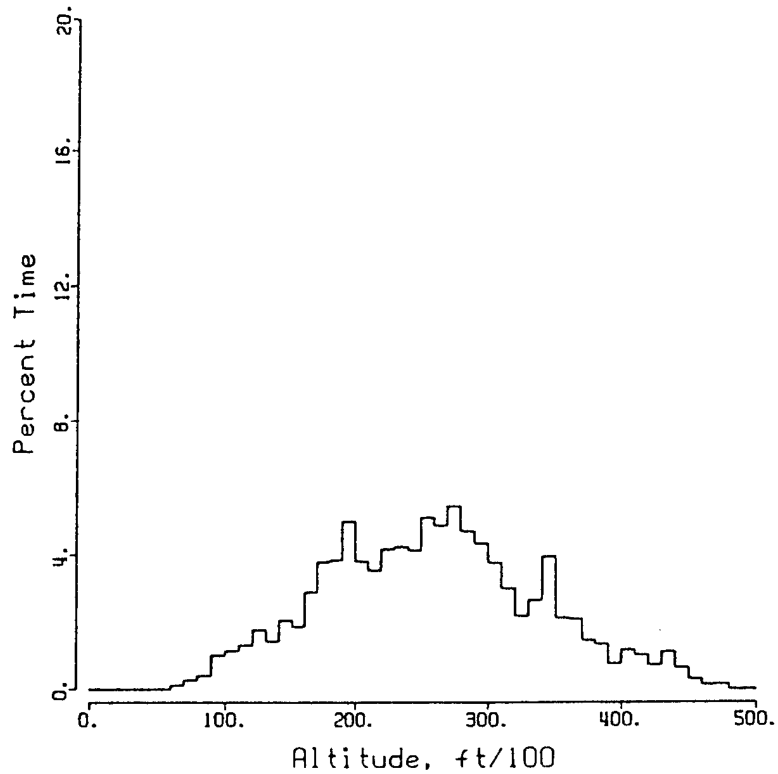


Figure A23. F-18 ACMI AGL Altitude Distribution.

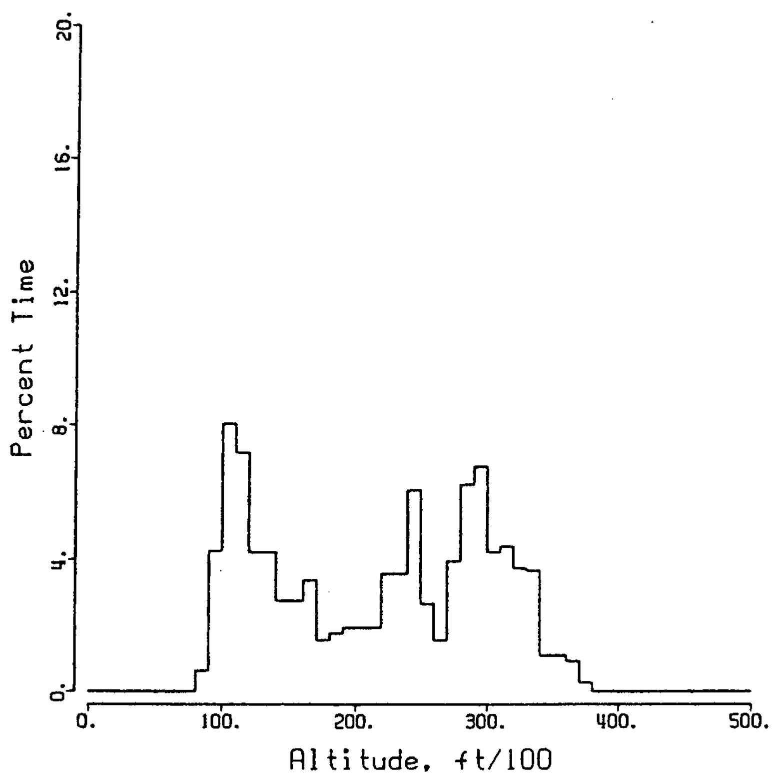


Figure A24. A-10 ACMI AGL Altitude Distribution.

APPENDIX B

Affected Environment

John E. Wesler
Wyle Laboratories

B.1 NOISE

B.1.1 General

Noise, often defined as unwanted sound, is the largest and most pervasive environmental problem associated with aircraft operations. Of course, aircraft are not the only sources of noise in an urban or suburban surrounding, where interstate and local roadway traffic, rail, industrial, and neighborhood sources also intrude on the everyday quality of life. Nevertheless, aircraft are readily identifiable to those affected by their noise, and are typically singled out for special attention and criticism. Consequently, aircraft noise problems often dominate analyses of environmental impacts.

Sound is a physical phenomenon, and consists of minute vibrations which travel through a medium, such as air, and are sensed by the human ear. Whether that sound is interpreted as pleasant (for example, music) or unpleasant (for example, aircraft noise) depends largely on the listener's current activity, past experience, and attitude toward the source of that sound. It is often true that one person's music is another person's noise.

The measurement and human perception of sound involves two basic physical characteristics – intensity and frequency. The intensity is a measure of the strength or amplitude of the sound vibrations, and is expressed in terms of sound pressure. The higher the sound pressure, the more intense and the louder is the perception of that sound. The second important physical characteristic is the sound frequency, or the number of times per second the sound vibrates or oscillates. Low-frequency sounds are characterized as rumbles or roars, while high-frequency sounds are typified by sirens or screeches.

The range of sound intensity (I) which can be detected comfortably by the human ear is extremely large, and covers a range from 1 to 1,000,000,000,000. Because of this vast range, any attempt to represent the sound intensity using a

linear scale becomes very unwieldy. As a result, a logarithmic unit known as the decibel (abbreviated dB) was borrowed from electrical engineering to represent sound level (L), and is defined as:

$$L = 10 \log_{10} (I/I_{ref}), \quad \text{decibels.}$$

where I_{ref} is a reference intensity (10^{-16} watt/sq.cm.).

Thus <u>sound intensity</u> is measured in terms of sound level, an open-ended scale ranging from 0 dB at the reference intensity, which is approximately the threshold of human hearing and is barely audible under extremely quiet listening conditions. Sound levels above about 120 dB begin to be felt inside the human ear as discomfort and eventually pain at still higher levels.

Because of the logarithmic nature of the decibel unit, sound levels cannot be added or subtracted directly, and are somewhat cumbersome to handle mathematically. However, some simple rules of thumb are useful in dealing with sound levels. First, if a sound's intensity is doubled, the sound level increases by 3 dB, regardless of the initial sound level. Thus, for example:

60 dB + 60 dB = 63 dB, or

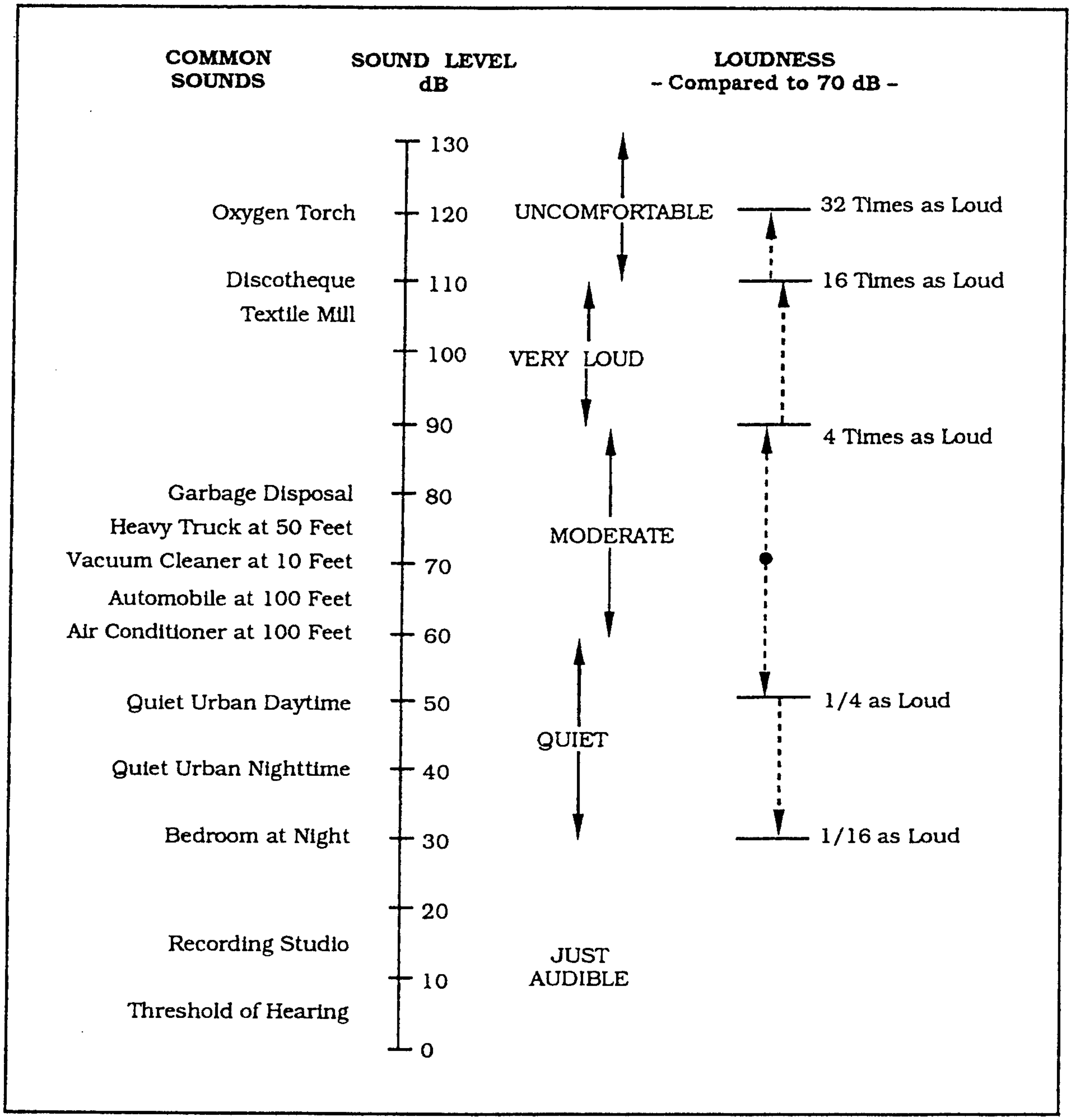
80 dB + 80 dB = 83 dB.

The sum of two sounds of different level is usually only slightly more than the higher level. For example:

60.0 dB + 70.0 dB = 70.4 dB.

An important facet of this characteristic arises later when the concept of time-average sound levels is considered. Because of the logarithmic unit, the time-average sound level is dominated by the loudest levels which occur during the averaging period. As a simple example, consider a sound level which is 100 dB and lasts for 30 seconds, followed by a sound level of 50 dB which also lasts for 30 seconds. The time-average sound level over the total 60-second period is 97 dB, not 75 dB as might be expected.

The minimum change in the sound level of individual events which an average human ear can detect is about 3 dB. A change in sound level of about 10 dB is usually perceived by the average person as a doubling (or halving) of the



Source: *Handbook of Noise Control*, C.M. Harris, Editor, McGraw-Hill Book Co., 1979

Figure B-1. Typical A-Weighted Sound Levels of Common Sounds.

B.1.2.1 Individual Event Maximum Sound Level

The highest sound level generated by a single noise event is measured in A-weighted Sound Level (abbreviated ALM), to take into account the maximum intensity of the emitted sound and the frequency sensitivity of the human ear. The sound levels of typical events are shown in Figure B-1. The maximum A-weighted Sound Level is important in judging the interference caused by a noise event with conversation, TV/radio listening, sleep, or other common activities. Maximum Sound Level is not an instantaneous sound level, but is actually an average over a very short interval of time, either one-eighth of a second, denoted "fast response", or one second, denoted "slow" response, to reflect the time constants incorporated into noise measurement instruments.

B.1.2.2 Sound Exposure Level

The maximum sound level alone may not represent just how intrusive a noise event is, because it does not consider the length of time that the noise persists. Sound Exposure Level (abbreviated SEL) takes into account an event's sound intensity, frequency content, and time duration, by measuring the total A-weighted sound energy of that event. Figure B-2 illustrates an idealized time pattern of the noise of an aircraft flyover, as the noise level rises above the ambient or background level to a maximum and then falls below the ambient as the aircraft passes.

The Sound Exposure Level is the A-weighted Sound Level integrated or summed over the entire noise event, represented by the cross-hatched area in Figure B-2, and is normalized to a reference duration of one second. For simplicity, this may be thought of as the maximum A-weighted Sound Level of an event which lasts exactly one second and contains the same total sound energy as the measured event. The one-second reference duration serves as a common denominator, allowing comparisons among different noise events of different durations. Sound Exposure Levels are measured in A-weighted Sound Level and are expressed in units of A-weighted decibels with the one-second reference duration understood but not stated. Unfortunately, this sometimes leads to confusion between maximum A-weighted Sound Level and Sound Exposure Level, so that the specific metric used should be stated clearly.

sound's loudness, and this relation holds true for loud sounds and for quieter sounds. A decrease in sound level of 10 dB actually represents a 90 percent decrease in sound intensity, but only a 50 percent decrease in perceived loudness because of the nonlinear response of the human ear (similar to most human senses).

Sound frequency is measured in terms of cycles per second (cps), or hertz (Hz), which is the preferred scientific unit for cps. The normal human ear can detect sounds which range in frequency from about 20 Hz to about 15,000 Hz. All sounds in this wide range of frequencies, however, are not heard equally well by the human ear, which is most sensitive to frequencies in the 1000 to 4000 Hz range. In measuring community noise, this frequency-dependence is taken into account by adjusting the very high and very low frequencies to approximate the human ear's lower sensitivity to those frequencies. This is called "A-weighting", and is commonly used in measurements of community environmental noise. Sound levels measured with the A-weighting are called A-weighted Sound Levels and are given in terms of A-weighted decibels, often abbreviated "dBA" or sometimes "dB(A)". In this environmental assessment, all sound levels will be recorded in A-weighted decibels, unless specifically indicated otherwise, and may be labeled as "dB" or "dBA" in different places. As long as the use of A-weighting is understood to be used, there is no difference implied by the different terms dB, dBA, or dB(A).

B.1.2 Noise Metrics

A "metric" is defined in the dictionary as something "of, involving, or used in measurement". As used in environmental noise analyses, a metric refers to the unit or quantity which measures or represents the effect of noise on people. Noise measurements have typically involved a confusing proliferation of noise metrics as individual researchers have attempted to understand and represent the effects of environmental noise. As a result, past literature describing noise abatement has included many different metrics. More recently, however, the various federal agencies involved in environmental noise mitigation have agreed on common metrics, and both the Department of Defense and the Federal Aviation Administration have specified those which should be used for Federal aviation noise assessments. These metrics are as follows.

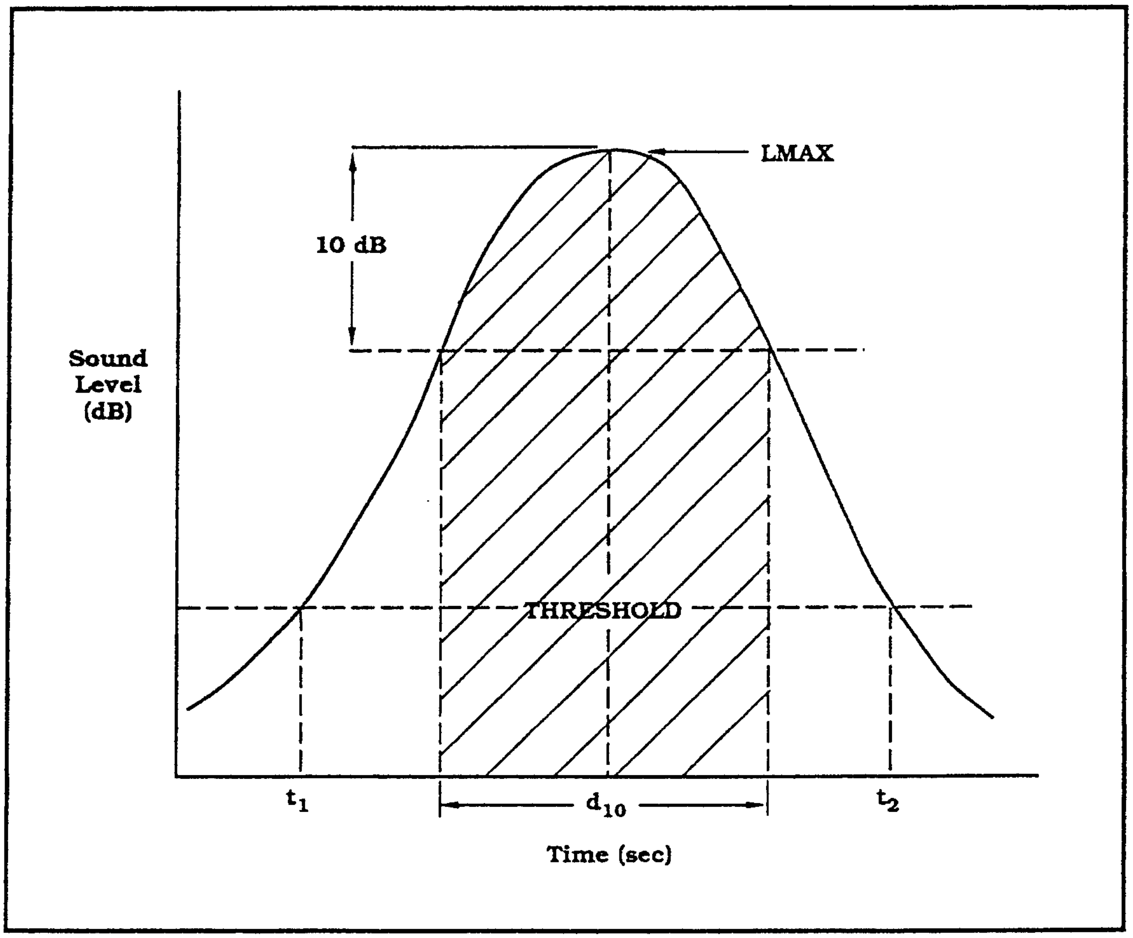


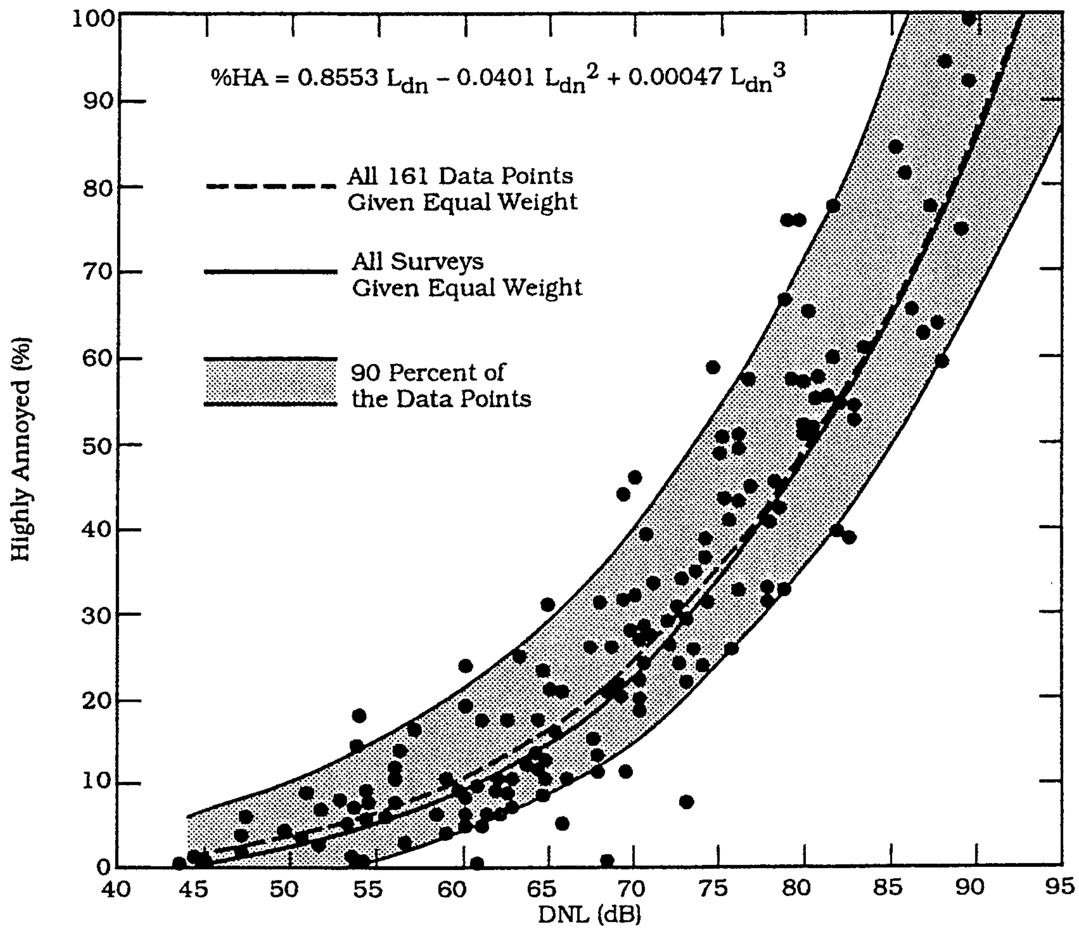
Figure B-2. Sound Exposure Level (SEL).

B.1.2.3 Day-Night Average Sound Level

Time-average sound levels are simply measurements of sound levels which are averaged over a specified length of time. These levels, sometimes referred to as cumulative sound levels or sound "doses", provide a measure of the total sound energy during the measurement period. For the evaluation of community noise effects, and particularly aircraft noise effects, the Day-Night Average Sound Level (abbreviated DNL, symbolized L_{dn}) is used. Day-Night Average Sound Level simply averages aircraft sound levels at a location over a complete 24-hour period, with a 10-decibel weighting added to those noise events which take place between 10:00 pm and 7:00 am (local time) the following morning. This 10-decibel "penalty" represents the added intrusiveness of sounds which occur during normal sleeping hours, both because of the increased sensitivity to noise during those hours and because ambient sound levels during nighttime are typically about 10 dB lower than during daytime hours.

Ignoring the 10-decibel weighting for the moment, Day-Night Average Sound Level may be thought of as the continuous A-weighted Sound Level which would be present if all of the variations in sound level which occur over a 24-hour period were smoothed out to contain the same total sound energy. Day-Night Average Sound Level provides a single measure of overall noise impact, but does not provide specific information on the number of noise events or the individual sound levels which occur during the day. For example, a Day-Night Average Sound Level of 65 dB could result from a very few noisy events, or a large number of quieter events. Nevertheless, scientific studies and social surveys which have been conducted to appraise community annoyance to all types of environmental noise have found the Day-Night Average Sound Level to be the best measure of that annoyance. Its use is endorsed by the scientific community (References 1 through 5).

In fact, there is a remarkable consistency in the results of attitudinal surveys about aircraft noise conducted in different countries to find the percentages of groups of people who express various degrees of annoyance when exposed to different levels of Day-Night Average Sound Level. This is illustrated in Figure B-3, which summarizes the results of a large number of social surveys relating community responses to various types of noises, measured in Day-Night Average Sound Level. Reference 6, from which Figure B-3 was taken, was



Source: "Synthesis of Social Surveys on Noise Annoyance", T. Schultz, *JASA*, Vol. 64 (1978)

Figure B-3. Community Surveys of Noise Annoyance.

published in 1978. A more recent study has reaffirmed this relationship (Reference 7). In general, correlation coefficients of 0.85 to 0.95 are found between the percentages of groups of people annoyed and the level of average noise exposure. The correlation coefficients for the annoyance of individuals are relatively low, however, on the order of 0.5 or less. This is not surprising, considering the varying personal factors which influence the manner in which individuals react to noise. Nevertheless, findings substantiate that community annoyance to aircraft noise is represented quite reliably using Day-Night Average Sound Level.

This relation between community annoyance and time-average sound level has been confirmed, even for infrequent aircraft noise events. Reference 8 reported the reactions of individuals in a community to daily helicopter overflights, ranging from one to 32 per day. The stated reactions correlated quite well with the daily time-average sound levels over this range of noise events.

The use of Day-Night Average Sound Level has been criticized recently as not accurately representing community annoyance and land-use compatibility with aircraft noise. Much of that criticism stems from a lack of understanding of the basis for the measurement or calculation of DNL. One frequent criticism is based on the inherent feeling that people react to single noise events, not a "meaningless" time-average sound level. In fact, a time-average noise metric, such as DNL, takes into account both the noise levels of all individual events which occur during a 24-hour period, and the number of times those events occur. As described briefly above, the logarithmic nature of the decibel unit causes the noise levels of the loudest events to control the 24-hour average. As a simple example of this characteristic, consider a case in which only one aircraft flyover occurs in daytime during a 24-hour period, and creates a sound level of 100 dB for 30 seconds. During the remaining 23 hours and 59.5 minutes of the day, the ambient sound level is 50 dB. The Day-Night Average Sound Level for this 24-hour period is 65.5 dB. Assume, as a second example, that ten such flyovers occur in daytime hours during the next 24-hour period, with the same ambient sound level of 50 dB during the remaining 23 hours and 55 minutes. The Day-Night Average Sound Level for this 24-hour period is 75.4 dB. Clearly, the averaging of noise over a 24-hour period does not ignore the louder single events, and tends to emphasize both the sound levels and number of those events. This is the basic concept of a time-average sound metric, and specifically Day-Night Average Sound Level.

B.1.2.4 Onset-Rate Adjusted Day-Night Average Sound Level

The nature of aircraft operations along low-level Military Training Routes (MTRs) generates a noise environment somewhat different from other community noise environments. Overflights are highly sporadic, ranging from five or ten per day to less than five per week. This situation differs from most community noise environments, which tend to continuous or patterned. Individual military noise events also differ from typical community noise events, because of the low altitude and high airspeed with which military aircraft operate along the MTRs.

To represent these differences, the conventional Day-Night Average Sound Level metric is adjusted to account for the "surprise" effect of the sudden onset of aircraft noise events in MTRs (Reference 9). For an aircraft event exhibiting a noise onset rate between 15 and 30 dB per second, an adjustment ranging from 0 to 5 dB is added to the normal Sound Exposure Level. For onset rates below 15 dB per second, no adjustment is made, while for rates above 30 dB per second, an adjustment of 5 dB is added. The Day-Night Average Sound Level is then determined in the same manner as for conventional aircraft noise events, and is designated as Onset-Rate Adjusted Day Night Average Sound Level (symbolized L_{dnmr}). Because of the sporadic occurrences of aircraft overflights along MTRs, the number of average daily operations is determined from the calendar month with the highest number of operations along each MTR.

B.1.3 Land-Use Compatibility

As noted above, the inherent variability between individuals makes it impossible to predict accurately how any one person will react to a given noise event. Nevertheless, when a community is considered as a whole, its overall reaction to noise can be represented with a high degree of confidence. As described above, the best noise exposure metric for this correlation is the Day-Night Average Sound Level (or Onset-Rate Adjusted Day Night Average Sound Level). In June 1980, an *ad hoc* Federal Interagency Committee on Urban Noise published Reference 4, relating Day-Night Average Sound Levels to compatible land uses. This committee was composed of representatives from the U.S. Departments of Defense, Transportation, and Housing and Urban Development, the Environmental Protection Agency, and the Veterans Administration.

Since the issuance of these guidelines, federal agencies have generally adopted these guidelines for their noise analyses.

Following the lead of the committee, the Department of Defense and the Federal Aviation Administration (FAA) adopted the concept of land-use compatibility as the accepted measure of aircraft noise effect. The FAA included the committee's guidelines in the Federal Aviation Regulations. These guidelines are reprinted in Table B-1, along with the explanatory notes included in the regulation. Although these guidelines are not mandatory, they provide the best means for determining noise impact in airport communities. In general, residential land uses normally are not compatible with outdoor Day-Night Average Sound Levels above 65 dB, and the extent of land areas and populations exposed to DNL of 65 dB and higher provides the best means for assessing the noise impacts of alternative aircraft noise abatement actions.

In 1990, a new Federal Interagency Committee on Noise was formed to review the manner in which aviation noise effects are assessed and presented. This group released its report in 1992, and reaffirmed the use of Day-Night Average Sound Level as the best metric for this purpose (Reference 5).

Analyses of aircraft noise impacts and compatible land uses around Department of Defense facilities are normally made using NOISEMAP and/or ROUTEMAP. These computer-based simulation programs calculate Day-Night Average Sound Level at many points on the ground around an airfield or aircraft operating area, and draw contours of equal level for overlay onto land-use maps of the same scale. Each program mathematically calculates the Sound Exposure Levels of all aircraft operations for a 24-hour period, taking into consideration the number and types of aircraft, their flight paths and engine thrust settings, the time of day (daytime or nighttime) that each operation occurs, and the onset rate, as appropriate. NOISEMAP and ROUTEMAP utilize the same physical models and aircraft performance data, and are collectively referred to as "NOISEMAP technology", or simply NOISEMAP.

NOISEMAP provides an accurate measure of noise effects around airfields. Of course, Day-Night Average Sound Levels may be measured directly around an airfield, rather than calculated with NOISEMAP. The direct measurement of an annualized Day-Night Average Sound Level is difficult and costly, of course, since it

Table B-1

Land-Use Compatibility With Yearly Day-Night Average Sound Levels

Land Use	Yearly Day-Night Average Sound Level (L_{dn}) in decibels					
	Below 65	65–70	70–75	75–80	80–85	Over 85
Residential						
Residential, other than mobile homes and transient lodgings	Y	N(1)	N(1)	N	N	N
Mobile home parks	Y	N	N	N	N	N
Transient lodgings	Y	N(1)	N(1)	N(1)	N	N
Public Use						
Schools	Y	N(1)	N(1)	N	N	N
Hospitals and nursing homes	Y	25	30	N	N	N
Churches, auditoria, and concert halls	Y	25	30	N	N	N
Governmental services	Y	Y	25	30	N	N
Transportation	Y	Y	Y(2)	Y(3)	Y(4)	Y(4)
Parking	Y	Y	Y(2)	Y(3)	Y(4)	N
Commercial Use						
Offices, business and professional	Y	Y	25	30	N	N
Wholesale and retail—building materials, hardware, and farm equipment	Y	Y	Y(2)	Y(3)	Y(4)	N
Retail trade—general	Y	Y	25	30	N	N
Utilities	Y	Y	Y(2)	Y(3)	Y(4)	N
Communication	Y	Y	25	30	N	N
Manufacturing and Production						
Manufacturing, general	Y	Y	Y(2)	Y(3)	Y(4)	N
Photographic and optical	Y	Y	25	30	N	N
Agriculture (except livestock) and forestry	Y	Y(6)	Y(7)	Y(8)	Y(8)	Y(8)
Livestock farming and breeding	Y	Y(6)	Y(7)	N	N	N
Mining and fishing, resource production and extraction	Y	Y	Y	Y	Y	Y
Recreational						
Outdoor sports arenas and spectator sports	Y	Y(5)	Y(5)	N	N	N
Outdoor music shells, amphitheaters	Y	N	N	N	N	N
Nature exhibits and zoos	Y	Y	N	N	N	N
Amusements, parks, resorts, and camps	Y	Y	Y	N	N	N
Golf courses, riding stables, and water recreation	Y	Y	25	30	N	N

Numbers in parentheses refer to notes.

* The designations contained in this table do not constitute a federal determination that any use of land covered by the program is acceptable or unacceptable under federal, state, or local law. The responsibility for determining the acceptable and permissible land uses and the relationship between specific properties and specific noise contours rests with the local authorities. FAA determinations under Part 150 are not intended to substitute federally determined land uses for those determined to be appropriate by local authorities in response to locally determined needs and values in achieving noise-compatible land uses.

KEY TO TABLE B-1

SLUCM = Standard Land-Use Coding Manual.
Y (Yes) = Land Use and related structures compatible without restrictions.
N (No) = Land Use and related structures are not compatible and should be prohibited.
NLR = Noise Level Reduction (outdoor to indoor) to be achieved through incorporation of noise attenuation into the design and construction of the structure.
25, 30, or 35 = Land Use and related structures generally compatible; measures to achieve NLR of 25, 30, or 35 dB must be incorporated into design and construction of structures.

NOTES FOR TABLE B-1

(1) Where the community determines that residential or school uses must be allowed, measures to achieve outdoor-to-indoor Noise Level Reduction (NLR) of at least 25 dB and 30 dB should be incorporated into building codes and be considered in individual approvals. Normal residential construction can be expected to provide an NLR of 20 dB; thus the reduction requirements are often stated as 5, 10, or 15 dB over standard construction and normally assume mechanical ventilation and closed windows year-round. However, the use of NLR criteria will not eliminate outdoor noise problems.
(2) Measures to achieve NLR 25 dB must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise-sensitive areas, or where the normal noise level is low.
(3) Measures to achieve NLR of 30 dB must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise-sensitive areas, or where the normal noise level is low.
(4) Measures to achieve NLR 35 dB must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise-sensitive areas, or where the normal level is low.
(5) Land-use compatible provided special sound reinforcement systems are installed.
(6) Residential buildings require an NLR of 25.
(7) Residential buildings require an NLR of 30.
(8) Residential buildings not permitted.

requires year-round monitoring or careful seasonal sampling. NOISEMAP is most accurate for comparing "before-and-after" noise impacts which would result from proposed airfield changes or alternative noise control actions, so long as the various impacts are calculated in a consistent manner. This environmental assessment will be based on the use of NOISEMAP to compare directly the noise impacts of alternative proposed deployment plans at Nellis Range and its associated military operating areas. NOISEMAP also has the flexibility of calculating sound levels at any specified grid point, so that noise levels at representative points under flight paths can be obtained directly.

B.2 NOISE EFFECTS

B.2.1 Hearing Loss

Noise-induced hearing loss is probably the best defined of the potential effects of human exposure to excessive noise. Federal workplace standards for protection from hearing loss allow a time-average level of 90 dB over an 8-hour work period, or 85 dB averaged over a 24-hour period. Even the most protective criterion (no measurable hearing loss for the most sensitive portion of the population at the ear's most sensitive frequency, 4000 Hz, after a 40-year exposure) suggests a time-average sound level of 70 dB over a 24-hour period. Since it is unlikely that airport neighbors will remain outside their homes 24 hours per day for extended periods of time, there is little possibility of hearing loss below a Day-Night Average Sound Level of 75 dB, and this level is extremely conservative.

B.2.2 Nonauditory Health Effects

Nonauditory health effects of long-term noise exposure, where noise may act as a risk factor, have never been found to occur at levels below those protective against noise-induced hearing loss, described above. Most studies attempting to clarify such health effects have found that noise exposure levels established for hearing protection will also protect against any potential nonauditory health effects, at least in workplace conditions. The best scientific summary of these findings was contained in the lead paper at the National Institute of Health Conference on Noise and Hearing Loss, held on 22–24 January 1990 in Washington, D.C.:

"The nonauditory effects of chronic noise exposure, when noise is suspected to act as one of the risk factors in the development of hypertension, cardiovascular disease, and other nervous disorders, have never been proven to occur as chronic manifestations at levels below these criteria (an average of 75 dBA for complete protection against hearing loss for an eight-hour day). At the recent (1988) International Congress on Noise as a Public Health Problem, most studies attempting to clarify such health effects did not find them at levels below the criteria protective of noise-induced hearing loss, and even above these criteria, results regarding such health effects were ambiguous. Consequently, one comes to the conclusion that establishing and enforcing exposure levels protecting against noise-induced hearing loss would not only solve the noise-induced hearing loss problem but also any potential nonauditory health effects in the work place." (Reference 10; parenthetical wording added for clarification.)

Although these findings were directed specifically at noise effects in the work place, they are equally applicable to aircraft noise effects in the community environment. Research studies regarding the nonauditory health effects of aircraft noise are ambiguous, at best, and often contradictory. Yet, even those studies which purport to find such health effects use time-average noise levels of 75 dB and higher for their research. For example, an often-quoted paper by two UCLA researchers apparently found a relation between aircraft noise levels under the approach path to Los Angeles International Airport (LAX) and increased mortality rates among the exposed residents. This study used an average noise exposure level greater than 75 dB for the "noise-exposed" population (Reference 11). Nevertheless, three other UCLA professors analyzed those same data and found no relation between noise exposure and mortality rates (Reference 12). As a second example, two other UCLA researchers used this same population near LAX to show a higher rate of birth defects in 1970–1972 when compared with a control group residing away from the airport (Reference 13). Based on this report, a separate group at the U.S. Center for Disease Control performed a more thorough study of populations near Atlanta's Hartsfield International Airport (ATL) for 1970–1972, and found no relation in their study of 17 identified categories of birth defects to aircraft noise levels above 65 dB

In summary, there is no scientific basis for a claim that potential health effects exist for aircraft time-average sound levels below 75 dB.

B.2.3 Annoyance

The primary effect of aircraft noise on exposed communities is one of annoyance. Noise annoyance is defined by the U.S. Environmental Protection Agency as any negative subjective reaction on the part of an individual or group (Reference 3). As noted in the discussion of Day-Night Average Sound Level above, community annoyance is best measured by that metric.

It is often suggested that a lower level of Day-Night Average Sound Level, such as 60 or 55 dB, be adopted as the threshold of community noise annoyance for airport environmental assessments. There is no technical reason why a lower level cannot be measured or calculated for comparison purposes. Nevertheless, a Day-Night Average Sound Level of 65 dB provides a valid basis for comparing and assessing community noise effects, represents a noise exposure level which is normally dominated by aircraft noise and not other community or nearby highway noise sources, and reflects the FAA's threshold for grant-in-aid funding of airport noise mitigation projects. Standards adopted by the U.S. Department of Housing and Urban Development also establish a DNL of 65 dB for eligibility for federally guaranteed home loans. For this environmental impact study, levels of Day-Night Average Sound Level equal to and greater than 65 dB will be used for assessing community noise impact.

B.2.4 Speech Interference

Speech interference associated with aircraft noise is a primary cause of annoyance to individuals on the ground. The disruption of routine activities such as radio or television listening, telephone use, or family conversation gives rise to frustration and irritation. The quality of speech communication is also important in classrooms, offices, and industrial settings, and can cause fatigue and vocal strain in those who attempt to communicate over the noise. Research has shown that the use of the Sound Exposure Level will measure speech interference successfully, and that a Sound Exposure Level exceeding 65 dB will begin to interfere with speech communication.

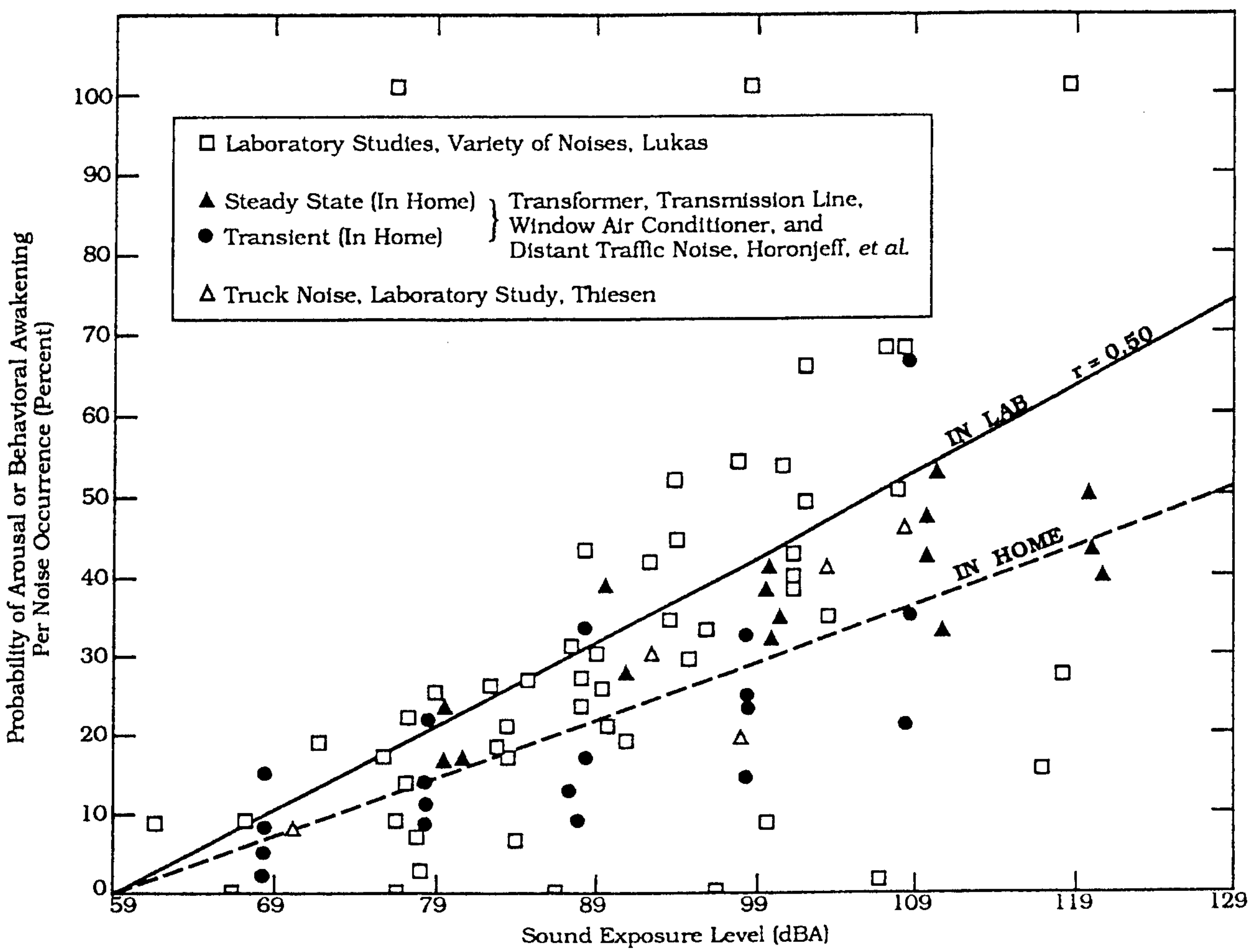
B.2.5 Sleep Interference

Sleep interference is another source of annoyance with aircraft noise. This is especially true because of the intermittent nature and content of aircraft noise, which is more disturbing than continuous noise of equal energy and neutral meaning. Sleep interference may be measured in either of two ways. "Arousal" represents actual awakening from sleep, while a change in "sleep stage" represents a shift from one of four sleep stages to another stage of lighter sleep without actual awakening. In general, arousal requires a somewhat higher noise level than does a change in sleep stage.

A recent analysis sponsored by the U.S. Air Force summarized 21 published studies concerning the effects of noise on sleep (Reference 15). The analysis concluded that a lack of reliable studies in homes, combined with large differences among the results from the various laboratory studies and the limited in-home studies, did not permit development of an acceptable assessment procedure. The noise events used in the laboratory studies and contrived in-home studies were presented at much higher rates of occurrence than would normally be experienced in the home. None of the laboratory studies was of sufficiently long duration to determine any effects of habituation, such as that which would occur under normal community conditions.

Nevertheless, some guidance is available in judging sleep interference. The U.S. Environmental Protection Agency identified an indoor Day-Night Average Sound Level of 45 dB as necessary to protect against sleep interference (Reference 3). Assuming a very conservative structural noise insulation of 20 dB for typical dwelling units, this corresponds to an outdoor Day-Night Average Sound Level of 65 dB as minimizing sleep interference.

A 1984 publication reviewed the probability of arousal or behavioral awakening in terms of Sound Exposure Level (Reference 16). Figure B-4, extracted from Figure 10.37 of Reference 16, indicates that an <u>indoor</u> Sound Exposure Level of 65 dB or lower should awaken less than 5 percent of those exposed. These results do not include any habituation over time by sleeping subjects. Nevertheless, this provides a reasonable guideline for assessing sleep interference, and corresponds to similar guidance for speech interference, as noted above.



Source: *Physiological, Psychological, and Social Effects of Noise*, Kryter, K.D., NASA Reference Publication 1115, p. 446, Figure 10.37.

Figure B-4. Probability of Arousal or Behavioral Awakening in Terms of Sound Exposure Level (Reference 15).

B.2.6 Noise Effects on Domestic Animals and Wildlife

Animal species differ greatly in their responses to noise. Each species has adapted, physically and behaviorally, to fill its ecological role in nature, and its hearing ability usually reflects that role. Animals rely on their hearing to avoid predators, obtain food, and communicate with and attract other members of their species. Aircraft noise may mask or interfere with these functions. Secondary effects may include nonauditory effects similar to those exhibited by humans – stress, hypertension, and other nervous disorders. Tertiary effects may include interference with mating, and population declines.

There are few scientific studies available regarding the effects of noise on wildlife, although some anecdotal reports of wildlife "flight" due to noise are available. Few of these studies or reports include any reliable measures of the noise levels involved. One study suggested that maximum A-weighted Sound Levels less than 70 dB generated by helicopters should produce little adverse effect on wild pronghorn antelopes. Another report, dealing with the environmental consequences of a proposed Arctic gas pipeline, observed temporary disturbances to grazing caribou, and sheep by helicopter overflights at altitudes of 300 to 1,000 feet. In general, it is reasonable to assume that noise levels which are protective of humans will also protect domestic animals and wildlife (Reference 18).

B.2.7 Noise Effects on Structures

Normally, the most sensitive components of a structure to airborne noise are the windows, and infrequently the plastered walls and ceilings. An evaluation of the peak sound pressures impinging on the structure is normally sufficient to determine the possibility of damage. In general, above sound levels of 130 dB, there is the possibility of the excitation of structural component resonances. While certain frequencies (such as 30 hertz for window breakage) may be of more concern than other frequencies, conservatively, only sounds lasting more than one second above a sound level of 130 dB are potentially damaging to structural components (Reference 18).

Noise-induced structural vibration may also cause annoyance to dwelling occupants, because of induced secondary vibrations, or "rattle", of objects within

the dwelling – hanging pictures, dishes, plaques, and other bric-a-brac. Window panes may also vibrate noticeably when exposed to high levels of airborne noise, causing fear of breakage for homeowners. In general, such noise-induced vibrations occur at sound levels above those considered normally incompatible with residential land use. Thus assessments of noise exposure levels for compatible land use should also be protective of noise-induced secondary vibrations.

B.2.8 Noise Effects on Terrain

It has been suggested that noise levels associated with low-flying aircraft may affect the terrain under the flight path, by disturbing fragile soil or snow structures, especially in mountainous areas, and cause landslides or avalanches. There are no known instances of such effects, and it is considered improbable that such effects will result from routine, subsonic aircraft operations. This is especially true, inasmuch as airfield approach and departure tracks, and Military Training Routes and Military Operating Areas involve relatively flat terrain.

B.2.9 Noise Effects on Historical and Archaeological Sites

Because of the potential for increased fragility of structural components of historical buildings and other historical sites, aircraft noise may affect such sites more severely than newer structures. Again, there are few scientific studies of such effects to provide guidance for their assessment.

One study involved the measurements of sound levels and structural vibration levels in a superbly restored plantation house, originally built in 1795, and now situated approximately 1,500 feet from the centerline at the departure end of Runway 19L at Washington Dulles International Airport (IAD). These measurements were made in connection with the proposed scheduled operation of the supersonic Concorde airplane at IAD (Reference 17). There was special concern for the building's windows, since roughly half of the 324 panes were original. No instances of structural damage were found. Interestingly, despite the high levels of noise during Concorde takeoffs, the induced structural vibration levels were actually less than those induced by touring groups and vacuum cleaning.

As noted above for the noise effects of noise-induced vibrations of normal structures, assessments of noise exposure levels for normally compatible land uses should also be protective of historic and archaeological sites.

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